Package: anglemania (via r-universe)

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URL https://github.com/BIMSBbioinfo/anglemania/

Title Feature Extraction for scRNA-seq Dataset Integration

Version 1.3.0

Description anglemania extracts genes from multi-batch scRNA-seq experiments for downstream dataset integration. It shows improvement over the conventional usage of highly-variable genes for many integration tasks. We leverage gene-gene correlations that are stable across batches to identify biologically informative genes which are less affected by batch effects. Currently, its main use is for single-cell RNA-seq dataset integration, but it can be applied for other multi-batch downstream analyses such as NMF.

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`anglemania` *anglemania*

Description

`anglemania` computes critical angles between genes across all samples provided in an SingleCellExperiment object. It calculates angles, transforms them to z-scores, computes statistical measures, and selects the top genes based on mean and standard deviation of z-scores. These genes are biologically informative and invariant to batch effects.

This function adds a unique batch identifier to the metadata of a `SingleCellExperiment` object by combining specified dataset and batch keys. This is useful for distinguishing samples during integration or analysis.

Usage

```
anglemania(
  sce,
  batch_key,
  dataset_key = NA_character_,
  max_n_genes = 2000,
  min_cells_per_gene = 1,
  min_samples_per_gene = 2,
  allow_missing_features = FALSE,
  method = "cosine",
  permute_row_or_column = "column",
  permutation_function = "sample",
  prefilter_threshold = 0.5,
  normalization_method = "divide_by_total_counts",
```

```
  verbose = TRUE
)

check_params(
  sce,
  batch_key,
  dataset_key,
  max_n_genes,
  method,
  min_cells_per_gene,
  min_samples_per_gene,
  allow_missing_features,
  permute_row_or_column,
  permutation_function,
  prefilter_threshold,
  normalization_method,
  verbose
)

add_unique_batch_key(sce, dataset_key = NA_character_, batch_key)

get_intersect_genes(
  matrix_list,
  allow_missing_features = FALSE,
  min_samples_per_gene = 1,
  verbose = TRUE
)
```

Arguments

sce	A SingleCellExperiment object.
batch_key	A character string specifying the column name in the metadata that identifies the batch.
dataset_key	A character string specifying the column name in the metadata that identifies the dataset. If NA, only the batch_key is used.
max_n_genes	Integer specifying the maximum number of genes to select.
min_cells_per_gene	Integer specifying the minimum number of cells per gene. Default is 1.
min_samples_per_gene	Integer indicating the minimum number of samples per gene.
allow_missing_features	Logical indicating whether to allow missing features.
method	Character string specifying the method to use for calculating the relationship between gene pairs. Default is "cosine". Other options include "spearman"
permute_row_or_column	Character "row" or "column", whether permutations should be executed row-wise or column wise. Default is "column"

permutation_function
: Character "sample" or "permute_nonzero". If sample,then sample is used for constructing background distributions. If permute_nonzero, then only non-zero values are permuted. Default is "sample"

prefilter_threshold
: Numeric value specifying the threshold prefiltering genes. Speeds up gene selection.

normalization_method
: Character "divide_by_total_counts" or "scale_by_total_counts". Default is "divide_by_total_counts"

verbose
: Logical indicating whether to print messages.

matrix_list
: A list of bigstatsr::FBM objects.

Details

This function performs the following steps:

1. Computes angles between genes for each batch in the SingleCellExperiment using the specified method, via factorise.
2. Transforms the angles to z-scores.
3. Computes statistical measures (mean z-score, signal-to-noise ratio) across batches using get_list_stats.
4. Selects the top n genes based on mean and standard deviation of z-scores using select_genes.

The computed statistics and selected genes are added to the SingleCellExperiment object, which is returned.

Value

An updated SingleCellExperiment object with computed statistics and selected genes. The results are stored in the metadata of the SingleCellExperiment object.

A list of validated parameters

A SingleCellExperiment object with an additional metadata column containing the unique batch key.

A character vector of intersected genes.

Functions

- check_params(): Check Parameters provided to the anglemania function
- add_unique_batch_key(): Temporarily add a unique batch key to the dataset
- get_intersect_genes(): Extract the intersected genes from a list of matrices (count matrices from different batches/datasets). It also allows for missing features in individual matrices, so that a feature does not have to be present in every single batch.

See Also

get_list_stats, select_genes, factorise, big_apply, https://arxiv.org/abs/1306.0256

Examples

```
# Set seed (optional)
set.seed(1)
sce <- sce_example()
sce <- anglemania(
  sce,
  batch_key = "batch",
  method = "cosine"
)

# Access the selected genes
selected_genes <- get_anglemania_genes(sce)
selected_genes[1:10]
sce <- sce_example()
params <- check_params(
  sce,
  batch_key = "batch",
  dataset_key = "dataset",
  max_n_genes = 2000,
  method = "cosine",
  min_cells_per_gene = 1,
  min_samples_per_gene = 2,
  allow_missing_features = FALSE,
  permute_row_or_column = "column",
  permutation_function = "sample",
  prefilter_threshold = 0.5,
  normalization_method = "divide_by_total_counts",
  verbose = TRUE
)
sce <- sce_example()
head(SummarizedExperiment::colData(sce))
sce <- add_unique_batch_key(
    sce,
    batch_key = "batch",
    dataset_key = "dataset"
)
head(SummarizedExperiment::colData(sce))
library(SingleCellExperiment)
sce <- sce_example()
barcodes_by_batch <- split(colnames(sce), colData(sce)$batch)
matrix_list <- lapply(barcodes_by_batch, function(barcodes) {
    SingleCellExperiment::counts(sce)[, barcodes]
})
intersect_genes <- get_intersect_genes(matrix_list)
head(intersect_genes)
```

`extract_angles` *Calculate cosine angle between genes*

Description

Constructs a matrix of gene-gene relationships based on distance metrics.

Usage

```
extract_angles(x_mat, method = "cosine")
```

Arguments

x_mat	An FBM object containing raw gene expression data, where rows correspond to genes and columns to samples. The data will be normalized and scaled within the function.
method	A character string specifying the method to compute the gene-gene relationships. Options are: • "cosine" (default): Computes the cosine angle between genes. • "spearman": Computes the Spearman rank correlation coefficient by rank-transforming the data before computing the correlation.

Details

The function returns the gene-gene angle matrix as an FBM object.

Value

An FBM object containing the gene-gene correlation matrix. The matrix is square with dimensions equal to the number of genes and contains the pairwise correlations between genes. The diagonal elements are set to NA.

See Also

big_apply, big_cor, FBM, factorise

Examples

```
mat <- matrix(
 c(
     5, 3, 0, 0,
     0, 0, 0, 3,
     2, 1, 3, 4,
     0, 0, 1, 0,
     1, 2, 1, 2,
     3, 4, 3, 4
   ),
   nrow = 6, # 6 genes
   ncol = 4, # 4 cells
   byrow = TRUE
)

mat <- bigstatsr::FBM(nrow = nrow(mat), ncol = ncol(mat), init = mat)
```

```
angle_mat <- extract_angles(mat)
angle_mat[]
```

`factorise` *Factorize Angle Matrices into Z-Scores*

Description

`factorise` computes the angle matrix of the input gene expression matrix using the specified method, performs permutation to create a null distribution, and transforms the correlations into z-scores. This function is optimized for large datasets using the **bigstatsr** package.

Usage

```
factorise(
  x_mat,
  method = "cosine",
  seed = 1,
  permute_row_or_column = "column",
  permutation_function = "sample",
  normalization_method = "divide_by_total_counts"
)
```

Arguments

`x_mat`	A `FBM` object representing the normalized and scaled gene expression matrix.
`method`	A character string specifying the method for calculating the relationship between gene pairs. Default is `"cosine"`. Other options include `"spearman"`
`seed`	An integer value for setting the seed for reproducibility during permutation. Default is 1.
`permute_row_or_column`	Character "row" or "column", whether permutations should be executed row-wise or column wise. Default is `"column"`
`permutation_function`	Character "sample" or "permute_nonzero". If sample, then sample is used for constructing background distributions. If permute_nonzero, then only non-zero values are permuted. Default is `"sample"`
`normalization_method`	Character "divide_by_total_counts" or "scale_by_total_counts". Default is `"divide_by_total_counts"`

Details

The function performs the following steps:

1. **Permutation**: The input matrix is permuted column-wise to disrupt existing angles, creating a null distribution.

2. **Angle Computation**: Computes the angle matrix for both the original and permuted matrices using `extract_angles`.
3. **Method-Specific Processing**:
   - For other methods (`"cosine"`, `"spearman"`), statistical measures are computed from the permuted data.
4. **Statistical Measures**: Calculates mean, variance, and standard deviation using `get_dstat`.
5. **Z-Score Transformation**: Transforms the original angle matrix into z-scores.

This process allows for the identification of invariant gene-gene relationships by comparing them to a null distribution derived from the permuted data.

Value

An `FBM` object containing the z-score-transformed angle matrix.

See Also

`extract_angles`, `get_dstat`, `big_apply`, `FBM`

Examples

```
mat <- matrix(
 c(
     5, 3, 0, 0,
     0, 0, 0, 3,
     2, 1, 3, 4,
     0, 0, 1, 0,
     1, 2, 1, 2,
     3, 4, 3, 4
   ),
   nrow = 6, # 6 genes
   ncol = 4, # 4 cells
   byrow = TRUE
)

mat <- bigstatsr::FBM(nrow = nrow(mat), ncol = ncol(mat), init = mat)

# Run factorise with method "cosine" and a fixed seed
result_fbm <- factorise(mat, method = "cosine", seed = 1)
result_fbm[]
```

`permute_nonzero` *permute non-zero elements of vectors*

Description

Permutes the non-zero elements of a numeric vector.

Usage

```
permute_nonzero(v)
```

Arguments

v	A numeric vector.

Value

A numeric vector with non-zero elements permuted.

Examples

```
v <- c(1, 2, 3, 4, 5, 6, 7, 8, 9, 10) # put in some zeroes
v = c(v, 0, 0, 0)
permute_nonzero(v)
```

---

sce_example *Generate example SingleCellExperiment object*

Description

This function generates a SingleCellExperiment object with 2 batches and 2 datasets. The object contains 300 genes and 600 cells. The counts matrix is generated using the `rpois` function with different lambda values for the two batches.

Usage

```
sce_example(seed = 42)
```

Arguments

seed	The seed for the random number generator. Because this function is only used locally, we allow to set a seed within the function.

Value

A SingleCellExperiment object

Examples

```
sce <- sce_example()
sce
```

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