Package 'spatialDE'

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Title R wrapper for SpatialDE

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Version 1.2.0

Description SpatialDE is a method to find spatially variable genes (SVG) from spatial transcriptomics data. This package provides wrappers to use the Python SpatialDE library in R, using reticulate and basilisk.

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URL https://github.com/sales-lab/spatialDE, https://bioconductor.org/packages/spatialDE/

BugReports https://github.com/sales-lab/spatialDE/issues

Depends R (>= 4.1)

Imports reticulate, basilisk, checkmate, stats, SpatialExperiment, methods, SummarizedExperiment, Matrix, S4Vectors, ggplot2, ggrepel, scales, gridExtra

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R topics documented:

`.importPyModule` *Import SpatialDE*

Description

This function loads the SpatialDE Python module and optionally monkey-patches it to remove tqdm calls.

Usage

```
.importPyModule(patch_tqdm)
```

Arguments

`patch_tqdm`	If `TRUE` patch calls to tqdm.

Value

An R wrapper for the SpatialDE Python module.

FSV_sig *Plot Fraction Spatial Variance vs Q-value*

Description

Plot Fraction Spatial Variance vs Q-value

Usage

```
FSV_sig(
  results,
  ms_results = NULL,
  certain_only = FALSE,
  log_x = FALSE,
  do_label = TRUE,
  covariate_names = NULL
)
```

Arguments

results	results from SpatialDE.
ms_results	model selection results, should be a data frame with columns g for gene names and model for the model selected.
certain_only	only plot results with narrow 95% confidence interval.
log_x	Whether to display x axis in log scale.
do_label	display gene names for statistically significant genes, default TRUE.
covariate_names	names of covariates as a reference, default to NULL.

Value

A ggplot2 object.

Author(s)

Davide Corso, Milan Malfait, Lambda Moses

References

Svensson, V., Teichmann, S. & Stegle, O. SpatialDE: identification of spatially variable genes. Nat Methods 15, 343–346 (2018). https://doi.org/10.1038/nmeth.4636

SpatialDE 1.1.3: the version of the Python package used under the hood.

Examples

```
set.seed(42)
spe <- mockSVG(size = 10, tot_genes = 200, de_genes = 20, return_SPE = TRUE)
## Run spatialDE with S4 integration
results <- spatialDE(spe)
## Run model search
msearch <- modelSearch(spe, de_results = results, qval_thresh = NULL,
  verbose = FALSE)

plot <- FSV_sig(results, msearch)
```

MOB_sample_info *Mouse Olfactory Bulb sample metadata*

Description

Coordinates and total counts for the samples from the Mouse Olfactory Bulb data generated by Stahl et al. (2016). This data was originally downloaded from https://github.com/Teichlab/SpatialDE/blob/master/Analysis/MouseOB/MOB_sample_info.csv.

Usage

```
MOB_sample_info
```

Format

A `data.frame` with 262 rows and 3 variables as columns: the `x` and `y` coordinates and `total_counts` corresponding to each spot.

References

Ståhl, P. L. et al. (2016) 'Visualization and analysis of gene expression in tissue sections by spatial transcriptomics', *Science*, 353(6294), p. 78. doi: 10.1126/science.aaf2403.

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mockSVG *Generate count matrix for spatially variable genes.*

Description

Generate count matrix for spatially variable genes.

Usage

```
mockSVG(size = 10, tot_genes = 1000, de_genes = 100, return_SPE = FALSE)
```

Arguments

`size`	An `integer` scalar. Cells will be spatially arranged on a `size x size` grid. Default: 10, corresponding to 100 cells.
`tot_genes`	An `integer` scalar. Total number of genes. Default: 1000.
`de_genes`	An `integer` scaler. The number of spatially variable genes. Default: 100.
`return_SPE`	A `logical`, whether to return result as a SpatialExperiment. Default: `FALSE`.

Value

If `return_SPE = TRUE`, returns a SpatialExperiment object.

If not, a `list` containing:

- `coordinates`: `data.frame` with `x` and `y` columns;
- `counts`: `matrix` with generated gene counts.

Examples

```
spe <- mockSVG(10, tot_genes = 200, de_genes = 20, return_SPE = TRUE)
spe
```

`modelSearch` *Classify Spatially Variable Genes to interpretable fitting classes*

Description

Compare model fits with different models, using the **SpatialDE** Python package.

Usage

```
modelSearch(x, de_results, ...)

## S4 method for signature 'matrix'
modelSearch(x, de_results, coordinates, qval_thresh = 0.05, verbose = FALSE)

## S4 method for signature 'SpatialExperiment'
modelSearch(
  x,
  de_results,
  assay_type = "counts",
  qval_thresh = 0.05,
  verbose = FALSE
)
```

Arguments

x	A numeric matrix of counts where genes are rows and cells are columns. Alternatively, a SpatialExperiment object.
de_results	data.frame resulting from run() or spatialDE().
...	For the generic, arguments to pass to specific methods.
coordinates	A data.frame with sample coordinates. Each row is a sample, the columns with coordinates should be named 'x' and 'y'. For the *SpatialExperiment* method, coordinates are taken from spatialCoords(x).
qval_thresh	numeric scalar, specifying the q-value significance threshold to filter de_results. Only rows in de_results with qval < qval_thresh will be kept. To disable, set qval_thresh = NULL.
verbose	A logical controlling the display of a progress bar from the Python package.
assay_type	A character string specifying the assay from x to use as input. Defaults to "counts".

Value

data.frame of model_search results.

Author(s)

Davide Corso, Milan Malfait, Lambda Moses

References

Svensson, V., Teichmann, S. & Stegle, O. SpatialDE: identification of spatially variable genes. Nat Methods 15, 343–346 (2018). https://doi.org/10.1038/nmeth.4636

SpatialDE 1.1.3: the version of the Python package used under the hood.

See Also

The individual steps performed by this function: stabilize(), regress_out() and model_search().

Examples

```
## Mock up a SpatialExperiment object wit 100 cells, 200 genes
set.seed(42)
spe <- mockSVG(size = 10, tot_genes = 200, de_genes = 20, return_SPE = TRUE)

## Run spatialDE with S4 integration
de_results <- spatialDE(spe)

## Run model search
model_search <- modelSearch(spe, de_results = de_results,
    qval_thresh = NULL, verbose = FALSE
)
```

model_search *Compare model fits with different models*

Description

Classify DE genes to interpretable fitting classes.

Usage

```
model_search(x, coordinates, de_results, qval_thresh = 0.05, verbose = FALSE)
```

Arguments

x	matrix-like object of normalized counts. E.g. resulting from regress_out().
coordinates	data.frame with sample coordinates. Each row is a sample, the columns with coordinates must be named 'x' and 'y'.
de_results	data.frame resulting from run().
qval_thresh	numeric scalar, specifying the q-value significance threshold to filter de_results. Only rows in de_results with qval < qval_thresh will be kept. To disable, set qval_thresh = NULL.
verbose	logical controlling the display of the progress bar.

Value

data.frame of model_search results.

References

Svensson, V., Teichmann, S. & Stegle, O. SpatialDE: identification of spatially variable genes. Nat Methods 15, 343–346 (2018). https://doi.org/10.1038/nmeth.4636

Examples

```
set.seed(42)
mock <- mockSVG(size = 10, tot_genes = 300, de_genes = 10)
stabilized <- stabilize(mock$counts)
sample_info <- mock$coordinates
sample_info$total_counts <- colSums(mock$counts)
regressed <- regress_out(counts = stabilized, sample_info = sample_info)

## Run SpatialDE
de_results <- run(regressed, coordinates = mock$coordinates)

## Run model search
ms_results <- model_search(
    x = regressed,
    coordinates = mock$coordinates,
    de_results = de_results,
```

```
    qval_thresh = NULL
)
```

`multiGenePlots` *Plot Spatial Patterns of Multiple Genes*

Description

Plot Spatial Patterns of Multiple Genes

Usage

```
multiGenePlots(x, ...)

## S4 method for signature 'matrix'
multiGenePlots(
  x,
  coordinates,
  genes_plot,
  viridis_option = "D",
  ncol = 2,
  point_size = 1,
  dark_theme = TRUE
)

## S4 method for signature 'SpatialExperiment'
multiGenePlots(
  x,
  assay_type = "counts",
  genes_plot,
  viridis_option = "D",
  ncol = 2,
  point_size = 1,
  dark_theme = TRUE
)
```

Arguments

`x`	A numeric `matrix` of stabilized counts (e.g. resulting from `stabilize()`) where genes are rows and cells are columns. Alternatively, a SpatialExperiment object.
`...`	For the generic, arguments to pass to specific methods.
`coordinates`	A `data.frame` with sample coordinates. Each row is a sample, the columns with coordinates should be named 'x' and 'y'. For the *SpatialExperiment* method, coordinates are taken from `spatialCoords(x)`.

genes_plot	character vector specifying which genes are to be plotted.
viridis_option	This function uses the viridis palette to color cells for gene expression. Four options are available: "magma" (or "A"), "inferno" (or "B"), "plasma" (or "C"), "viridis" (or "D", the default option) and "cividis" (or "E").
ncol	Number of columns to arrange the plots.
point_size	Point size of each plot.
dark_theme	Whether dark background should be used; this is helpful to highlight cells with high expression when using the viridis palette.
assay_type	A character string specifying the assay from x to use as input. Defaults to "counts".

Value

This function draws a plot for each specified genes

Author(s)

Davide Corso, Milan Malfait, Lambda Moses

References

Svensson, V., Teichmann, S. & Stegle, O. SpatialDE: identification of spatially variable genes. Nat Methods 15, 343–346 (2018). https://doi.org/10.1038/nmeth.4636

SpatialDE 1.1.3: the version of the Python package used under the hood.

See Also

The individual steps performed by this function: stabilize(), spatialDE().

For further analysis of the DE results: model_search() and spatial_patterns().

Examples

```
## Mock up a SpatialExperiment object wit 100 cells, 200 genes
set.seed(42)
spe <- mockSVG(size = 10, tot_genes = 200, de_genes = 10, return_SPE = TRUE)

## Run spatialDE
results <- spatialDE(spe)

ordered_spe_results <- results[order(results$qval), ]
head(ordered_spe_results)

plots <- multiGenePlots(spe,
    assay_type = "counts",
    ordered_spe_results[1:4, ]$g,
    point_size = 4,
    viridis_option = "D"
)
```

regress_out *Regress out library size effect*

Description

Regresses out the effect of library size. This function is a wrapper for `regress_out` from the NaiveDE Python package.

Usage

```
regress_out(counts, sample_info)
```

Arguments

`counts`	`matrix` of variance stabilized counts, e.g. resulting from `stabilize()`.
`sample_info`	`data.frame` with samples as rows and at least a column with `total_counts`.

Value

`matrix` of normalized counts.

Examples

```
set.seed(42)
mock <- mockSVG(10, 1000, 10)
stabilized <- stabilize(mock$counts)
sample_info <- mock$coordinates
sample_info$total_counts <- colSums(mock$counts)
regressed <- regress_out(counts = stabilized, sample_info = sample_info)
```

Rep11_MOB_0 *Mouse Olfactory Bulb spatial gene expression data*

Description

Replicate 11 from the spatially dependent gene expression data from the mouse olfactory bulb generated by Stahl et al. (2016). This data was originally downloaded from https://github.com/Teichlab/SpatialDE/blob/master/Analysis/MouseOB/data/Rep11_MOB_0.csv.

Usage

```
Rep11_MOB_0
```

Format

A matrix with 16218 genes as rows and 262 spots as columns.

References

Ståhl, P. L. et al. (2016) 'Visualization and analysis of gene expression in tissue sections by spatial transcriptomics', *Science*, 353(6294), p. 78. doi: 10.1126/science.aaf2403.

`run` *Perform SpatialDE test*

Description

Wraps the `run` function from the SpatialDE Python package.

Usage

```
run(x, coordinates, verbose = FALSE)
```

Arguments

`x`	`matrix`-like object of normalized counts. E.g. resulting from `regress_out()`.
`coordinates`	`data.frame` with sample coordinates. Each row is a sample, the columns with coordinates must be named 'x' and 'y'.
`verbose`	`logical` controlling the display of the progress bar.

Value

A `data.frame` with DE results where each row is a gene and columns contain relevant statistics.

The most important columns are:

- `g`: the name of the gene
- `pval`: the p-value for spatial differential expression
- `qval`: the q-value, indicating significance after correcting for multiple testing
- `l`: A parameter indicating the distance scale a gene changes expression over

References

Svensson, V., Teichmann, S. & Stegle, O. SpatialDE: identification of spatially variable genes. Nat Methods 15, 343–346 (2018). https://doi.org/10.1038/nmeth.4636

Examples

```
set.seed(42)
mock <- mockSVG(size = 10, tot_genes = 500, de_genes = 10)
stabilized <- stabilize(mock$counts)
sample_info <- mock$coordinates
sample_info$total_counts <- colSums(mock$counts)
regressed <- regress_out(counts = stabilized, sample_info = sample_info)

## Run SpatialDE
de_results <- run(regressed, coordinates = mock$coordinates)
```

spatialDE *Find spatially variable genes with* **SpatialDE**

Description

Identify genes that significantly depend on spatial coordinates with the **SpatialDE** Python package.

Usage

```
spatialDE(x, ...)

## S4 method for signature 'matrix'
spatialDE(x, coordinates, verbose = FALSE)

## S4 method for signature 'SpatialExperiment'
spatialDE(x, assay_type = "counts", verbose = FALSE)
```

Arguments

x	A numeric matrix of counts where genes are rows and cells are columns. Alternatively, a SpatialExperiment object.
...	For the generic, arguments to pass to specific methods.
coordinates	A data.frame with sample coordinates. Each row is a sample, the columns with coordinates should be named 'x' and 'y'. For the *SpatialExperiment* method, coordinates are taken from spatialCoords(x).
verbose	A logical controlling the display of a progress bar from the Python package.
assay_type	A character string specifying the assay from x to use as input. Defaults to "counts".

Value

A data.frame with DE results where each row is a gene and columns contain relevant statistics.

The most important columns are:

- g: the name of the gene
- pval: the p-value for spatial differential expression
- qval: the q-value, indicating significance after correcting for multiple testing
- l: A parameter indicating the distance scale a gene changes expression over

Author(s)

Davide Corso, Milan Malfait, Lambda Moses

References

Svensson, V., Teichmann, S. & Stegle, O. SpatialDE: identification of spatially variable genes. Nat Methods 15, 343–346 (2018). https://doi.org/10.1038/nmeth.4636

SpatialDE 1.1.3: the version of the Python package used under the hood.

See Also

The individual steps performed by this function: `stabilize()`, `regress_out()` and `run()`.

For further analysis of the DE results: `model_search()` and `spatial_patterns()`.

Examples

```
## Mock up a SpatialExperiment object wit 100 cells, 200 genes
set.seed(42)
spe <- mockSVG(size = 10, tot_genes = 200, de_genes = 20, return_SPE = TRUE)

## Run spatialDE
de_results <- spatialDE(spe)

head(de_results)
```

`spatialPatterns` *Automatic expression histology in* **SpatialDE**

Description

Group spatially variable genes into spatial patterns using Automatic Expression Histology, using the **SpatialDE** Python package.

Usage

```
spatialPatterns(x, de_results, ...)

## S4 method for signature 'matrix'
spatialPatterns(
  x,
  de_results,
  coordinates,
  qval_thresh = 0.05,
  n_patterns,
  length,
  verbose = FALSE
)

## S4 method for signature 'SpatialExperiment'
spatialPatterns(
```

```
  x,
  de_results,
  qval_thresh = 0.05,
  n_patterns,
  length,
  assay_type = "counts",
  verbose = FALSE
)
```

Arguments

x	A numeric `matrix` of counts where genes are rows and cells are columns. Alternatively, a SpatialExperiment object.
de_results	`data.frame` resulting from `run()` or `spatialDE()`.
...	For the generic, arguments to pass to specific methods.
coordinates	A `data.frame` with sample coordinates. Each row is a sample, the columns with coordinates should be named 'x' and 'y'. For the *SpatialExperiment* method, coordinates are taken from `spatialCoords(x)`.
qval_thresh	`numeric` scalar, specifying the q-value significance threshold to filter `de_results`. Only rows in `de_results` with `qval` < `qval_thresh` will be kept. To disable, set `qval_thresh = NULL`.
n_patterns	`integer` The number of spatial patterns
length	`numeric` The characteristic length scale of the clusters
verbose	A `logical` controlling the display of a progress bar from the Python package.
assay_type	A `character` string specifying the assay from `x` to use as input. Defaults to `"counts"`.

Value

A `list` of two `data.frames` (pattern_results, patterns):

- `pattern_results`: `data.frame` with pattern membership information for each gene.
- `patterns` the posterior mean underlying expression from genes in given spatial patterns.

Author(s)

Davide Corso, Milan Malfait, Lambda Moses

References

Svensson, V., Teichmann, S. & Stegle, O. SpatialDE: identification of spatially variable genes. Nat Methods 15, 343–346 (2018). https://doi.org/10.1038/nmeth.4636

SpatialDE 1.1.3: the version of the Python package used under the hood.

See Also

The individual steps performed by this function: `stabilize()`, `regress_out()` and `spatial_patterns()`.

Examples

```
## Mock up a SpatialExperiment object wit 100 cells, 200 genes
set.seed(42)
spe <- mockSVG(size = 10, tot_genes = 200, de_genes = 20, return_SPE = TRUE)

## Run spatialDE
de_results <- spatialDE(spe)

spatial_patterns <- spatialPatterns(spe, de_results = de_results,
    qval_thresh = NULL, n_patterns = 4L, length = 1.5,
    verbose = FALSE
)

head(spatial_patterns$pattern_results)
head(spatial_patterns$patterns)
```

---

spatial_patterns *Group spatially variable genes into spatial patterns using automatic expression histology (AEH)*

Description

Group spatially variable genes into spatial patterns using automatic expression histology (AEH)

Usage

```
spatial_patterns(
  x,
  coordinates,
  de_results,
  qval_thresh = 0.05,
  n_patterns,
  length,
  verbose = FALSE
)
```

Arguments

x	matrix-like object of normalized counts. E.g. resulting from regress_out().
coordinates	data.frame with sample coordinates. Each row is a sample, the columns with coordinates must be named 'x' and 'y'.
de_results	data.frame resulting from run().
qval_thresh	numeric scalar, specifying the q-value significance threshold to filter de_results. Only rows in de_results with qval < qval_thresh will be kept. To disable, set qval_thresh = NULL.
n_patterns	integer The number of spatial patterns

length	numeric The characteristic length scale of the clusters
verbose	logical controlling the display of the progress bar.

Value

list of two dataframe (pattern_results, patterns): pattern_results dataframe with pattern membership information for each gene. patterns the posterior mean underlying expression fro genes in given spatial patterns.

References

Svensson, V., Teichmann, S. & Stegle, O. SpatialDE: identification of spatially variable genes. Nat Methods 15, 343–346 (2018). https://doi.org/10.1038/nmeth.4636

Examples

```
set.seed(42)
mock <- mockSVG(size = 10, tot_genes = 500, de_genes = 10)
stabilized <- stabilize(mock$counts)
sample_info <- mock$coordinates
sample_info$total_counts <- colSums(mock$counts)
regressed <- regress_out(counts = stabilized, sample_info = sample_info)

## Run SpatialDE
de_results <- run(x = regressed, coordinates = mock$coordinates)

## Run Spatial_patterns
sp <- spatial_patterns(
    x = regressed,
    coordinates = mock$coordinates,
    de_results = de_results,
    qval_thresh = NULL,
    n_patterns = 5, length = 1.5
)

sp$pattern_results
sp$patterns
```

---

stabilize *Stabilize variance of counts*

Description

Stabilize variance of negative binomial data using Anscombe's approximation. This function is a wrapper for stabilize from the NaiveDE Python package.

Usage

```
stabilize(counts)
```

Arguments

counts	matrix with expression values for samples in columns and genes in rows.

Value

matrix of variance stabilized counts.

Examples

```
set.seed(42)
mock <- mockSVG(10, 1000, 10)
stabilized <- stabilize(mock$counts)
```

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