Package: RankMap (via r-universe)

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Title Rank-based reference mapping for fast and robust cell type annotation in spatial and single-cell transcriptomics

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Description RankMap is a fast and scalable tool for reference-based cell type annotation of single-cell and spatial transcriptomics data. It uses ranked gene expression and multinomial regression to achieve robust predictions, even with partial gene coverage. Compatible with Seurat, SingleCellExperiment, and SpatialExperiment objects, RankMap offers flexible preprocessing and significantly faster runtime than tools like SingleR, Azimuth, and RCTD.

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`computeRankedMatrix` *Compute Ranked Gene Expression Matrix*

Description

This function transforms a gene expression matrix by applying top-k filtering, optional rank transformation, binning, scaling, and/or expression weighting.

Usage

```
computeRankedMatrix(
  data,
  weight_by_expr = TRUE,
  rank_zeros = FALSE,
  bin_rank = TRUE,
  scale_rank = TRUE,
  k = 20,
  use_data = FALSE
)
```

Arguments

`data`	A gene expression matrix with genes as rows and cells (or spatial spots) as columns. Can be a dense numeric matrix, or a sparse `dgCMatrix`.
`weight_by_expr`	Logical. Whether to weight the ranks by log-transformed expression values. Default is `TRUE`.

rank_zeros	Logical. Whether to include zero values in the ranking. Default is FALSE.
bin_rank	Logical. Whether to discretize ranks into bins. Default is TRUE.
scale_rank	Logical. Whether to z-score normalize the ranks across columns. Default is TRUE.
k	Integer. Number of top expressed genes to retain per column. Default is 20.
use_data	Logical. If TRUE, returns the full input expression matrix (unfiltered and unranked). Default is FALSE.

Details

If use_data = TRUE, the function bypasses all transformation steps and returns the full input expression matrix. This is useful for benchmarking performance of rank-based versus raw log-normalized expression models.

Value

A numeric matrix of ranked expression values (or the original expression matrix if use_data = TRUE). Output is always returned as a dense matrix.

See Also

maskTopKGenes, trainRankModel, predictRankModel

Examples

```
mat <- matrix(runif(1000), nrow = 100)
ranked <- computeRankedMatrix(mat, k = 10)
raw_expr <- computeRankedMatrix(mat, use_data = TRUE)
```

---

evaluatePredictionPerformance

Evaluate Prediction Accuracy and Confusion by Cell Type

Description

Computes overall accuracy, per-class accuracy, and confusion matrix given predicted vs. true labels.

Usage

```
evaluatePredictionPerformance(
  prediction_df = NULL,
  truth = NULL,
  low_conf_label = "unknown"
)
```

Arguments

prediction_df	Output from predictRankModel (return_confidence = TRUE) or filtered version.
truth	A vector of true labels matching prediction_df.
low_conf_label	Character. Label used for low-confidence predictions (e.g., "unknown" or "uncertain"). These will be excluded from evaluation. Set to NULL to include all predictions.

Value

A list with:

overall_accuracy
: Proportion of correct predictions

per_class_accuracy
: Accuracy per true cell type

confusion_matrix
: Contingency table (true × predicted)

Examples

```
# Read in single-cell reference data
seu_sc <- readRDS(system.file("extdata", "seu_sc.rds",
    package = "RankMap"
))

# Read in Xenium spatial data
seu_xen <- readRDS(system.file("extdata", "seu_xen.rds",
    package = "RankMap"
))

# Predict cell type for Xenium data
prediction_df <- RankMap(
    ref_data = seu_sc,
    ref_labels = seu_sc$cell_type,
    new_data = seu_xen
)

performance <- evaluatePredictionPerformance(
    prediction_df = prediction_df,
    truth = seu_xen$cell_type_SingleR
)
performance
```

extractData — *Extract Expression Matrix from Seurat, SummarizedExperiment, or Matrix*

Description

Extracts a gene expression matrix from a `Seurat` object (default assay and `"data"` slot), a `SummarizedExperiment` object (assay named `"logcounts"`), or returns the input matrix if it is already a dense or sparse matrix.

Usage

```
extractData(data)
```

Arguments

`data`	A `Seurat` object, a `SummarizedExperiment` object, a dense numeric matrix, or a sparse matrix of class `dgCMatrix`

Value

A numeric gene expression matrix (dense or sparse), with genes as rows and cells or spots as columns.

Examples

```
seu_sc <- readRDS(system.file("extdata", "seu_sc.rds",
    package = "RankMap"
))

# From Seurat object:
mat <- extractData(seu_sc)
```

factorSorted — *Order factor levels by frequency*

Description

Takes a vector, converts it to a factor, and reorders its levels by their frequency of occurrence (most to least frequent by default).

Usage

```
factorSorted(x, decreasing = TRUE)
```

Arguments

x	A vector (character or factor) to be reordered by level frequency.
decreasing	Logical. If TRUE (default), levels are ordered from most to least frequent; if FALSE, from least to most frequent.

Details

Frequencies are computed with `table(x)`, which ignores `NA` values by default. `NA` entries in `x` are preserved in the output but are not considered a level.

Value

A factor with levels ordered by frequency.

Examples

```
factorSorted(c("a", "b", "a", "c", "b", "a"))
factorSorted(c("a", "b", "a", "c", "b", "a"), decreasing = FALSE)
factorSorted(factor(c("x", "y", "x", NA)))
```

---

filterLowConfidenceCells

Tag Low-Confidence Predictions and Add Status Column

Description

Replaces low-confidence cell type predictions with a placeholder label (e.g., "unknown") and adds a confidence status column ("confident" or "uncertain").

Usage

```
filterLowConfidenceCells(
  prediction_df,
  threshold = 0.5,
  low_conf_label = "unknown",
  keep_confidence = TRUE
)
```

Arguments

prediction_df	A data frame from `predictRankModel` (`return_confidence = TRUE`).
threshold	Numeric. Confidence threshold below which predictions are flagged. Default is `0.5`.
low_conf_label	Character. Replacement for low-confidence predictions. Default is `"unknown"`.
keep_confidence	Logical. Whether to retain the original `confidence` column. Default is `TRUE`.

Value

A data frame with columns: `cell_id`, `predicted_cell_type`, `status`, nd optionally `confidence`.

Examples

```
# Simulated predictions with confidence
pred_df <- data.frame(
    cell_id = paste0("cell", 1:5),
    predicted_cell_type = c("B", "T", "B", "Myeloid", "T"),
    confidence = c(0.92, 0.47, 0.88, 0.33, 0.76)
)

# Apply threshold of 0.5 to flag low-confidence cells
result <- filterLowConfidenceCells(pred_df, threshold = 0.5)

# Show result
print(result)

# Remove confidence column and use custom label
# for low-confidence predictions
result2 <- filterLowConfidenceCells(pred_df,
    threshold = 0.6,
    low_conf_label = "low_conf",
    keep_confidence = FALSE
)
```

`maskTopKGenes` *Mask Non-Top-K Genes in Each Cell or Spot*

Description

This function zeroes out all but the top-k most highly expressed genes in each column of a gene expression matrix. It supports both dense and sparse inputs.

Usage

```
maskTopKGenes(data, k = 20)
```

Arguments

`data`	A gene expression matrix with genes as rows and cells (or spatial spots) as columns. Can be a dense numeric matrix, or a sparse `dgCMatrix`.
`k`	Integer. Number of top expressed genes to retain per column. Default is `20`.

Value

A dense numeric matrix with the same dimensions as `data`, with only the top-k values retained per column.

Examples

```
mat <- matrix(runif(1000), nrow = 100)
masked <- maskTopKGenes(mat, k = 10)
```

`optimizeConfidenceThreshold` *Optimize Confidence Threshold for Cell Type Prediction*

Description

Finds the confidence threshold that best balances prediction accuracy and retention rate. Requires ground truth labels for comparison.

Usage

```
optimizeConfidenceThreshold(
  prediction_df,
  truth,
  thresholds = seq(0.1, 0.9, by = 0.05),
  plot = TRUE
)
```

Arguments

`prediction_df`	A data frame from `predictRankModel` (`return_confidence = TRUE`).
`truth`	A character or factor vector of true labels, aligned with rows of `prediction_df`.
`thresholds`	Numeric vector of thresholds to test. Default is seq(0.1, 0.9, by = 0.05).
`plot`	Logical. If `TRUE`, generates a plot of accuracy vs. threshold. Default is `TRUE`.

Value

A data frame summarizing accuracy and retained cell count at each threshold.

Examples

```
# Simulated prediction data
pred_df <- data.frame(
    cell_id = paste0("cell", 1:10),
    predicted_cell_type = c(
        "A", "B", "A", "B", "A",
        "B", "A", "A", "B", "B"
    ),
    confidence = c(
        0.95, 0.87, 0.65, 0.48, 0.92,
        0.55, 0.73, 0.33, 0.99, 0.60
    )
```

```
)

# Ground truth labels
truth <- c("A", "B", "A", "B", "B", "B", "A", "A", "B", "B")

# Evaluate how accuracy and coverage change with threshold
summary_df <- optimizeConfidenceThreshold(pred_df, truth, plot = TRUE)

# View result
print(summary_df)
```

`predictRankModel` *Predict Cell Types, Probabilities, or Confidence Scores*

Description

Predicts cell type labels or class probabilities using a trained RankMap model. Supports both `glmnet` and `cv.glmnet`. Optionally returns a data frame with predicted cell types and confidence scores.

Usage

```
predictRankModel(
  model,
  new_data,
  lambda = NULL,
  return_probs = FALSE,
  return_confidence = FALSE,
  ...
)
```

Arguments

`model`	A fitted model from `trainRankModel`.
`new_data`	A gene expression matrix with genes as rows and cells (or spatial spots) as columns. Can be a `Seurat` object, a `SummarizedExperiment` object, a dense numeric matrix, or a sparse `dgCMatrix`.
`lambda`	Optional lambda value. If `NULL`, uses `lambda.min` (if available), else `0.01`.
`return_probs`	Logical. If `TRUE`, returns the full matrix of class probabilities.
`return_confidence`	Logical. If `TRUE`, returns a data frame with predicted labels and confidence scores.
`...`	Additional arguments passed to `computeRankedMatrix`.

Value

A character vector (default), a matrix (if `return_probs = TRUE`), or a data frame (if `return_confidence = TRUE`).

Examples

```
# Read in single-cell reference data
seu_sc <- readRDS(system.file("extdata", "seu_sc.rds",
    package = "RankMap"
))

# Read in Xenium spatial data
seu_xen <- readRDS(system.file("extdata", "seu_xen.rds",
    package = "RankMap"
))

# Extract normalized expression data
common_genes <- intersect(rownames(seu_sc), rownames(seu_xen))
mat <- extractData(seu_sc)[common_genes, ]
new_mat <- extractData(seu_xen)[common_genes, ]

# Train a model
set.seed(42)
model <- trainRankModel(mat, seu_sc$cell_type)

# Predict cell type
pred <- predictRankModel(model, new_mat)

table(predict = pred, truth = seu_xen$cell_type_SingleR)
```

`RankMap` *RankMap: Train and Predict Cell Types Using Top-Ranked Genes*

Description

A unified function that trains a multinomial classifier on reference expression data and predicts cell types for a new dataset using top-k ranked genes. Automatically matches genes between datasets, optionally performs cross-validation, and returns predictions with confidence scores or probabilities.

Usage

```
RankMap(
  ref_data = NULL,
  ref_labels = NULL,
  new_data = NULL,
  n_feature_max = 500,
  k = 20,
```

```
  alpha = 0.1,
  cv = FALSE,
  nfolds = 5,
  lambda = NULL,
  return_probs = FALSE,
  return_confidence = TRUE,
  threshold = NULL,
  return_model = FALSE,
  ...
)
```

Arguments

ref_data	Reference gene expression matrix (genes x cells), a Seurat object, or a SummarizedExperiment object.
ref_labels	A character or factor vector of cell type labels for columns of ref_data.
new_data	New data to annotate. Same format as ref_data (matrix, dgCMatrix, Seurat object or SummarizedExperiment object).
n_feature_max	Maximum number of genes to use when more than 500 genes are shared. Default is 500.
k	Number of top expressed genes to retain per cell (ranking). Default is 20.
alpha	Elastic net mixing parameter for glmnet. Default is 0.1.
cv	Logical. Whether to use cv.glmnet for cross-validation. Default is FALSE.
nfolds	Number of folds for cross-validation. Default is 5.
lambda	Optional lambda value for prediction. If NULL, uses lambda.min from CV or defaults to 0.01.
return_probs	Logical. If TRUE, returns full class probability matrix. Default is FALSE.
return_confidence	Logical. If TRUE, returns prediction with confidence score and status. Default is TRUE.
threshold	Optional numeric threshold. If set and return_confidence = TRUE, predictions below this confidence are labeled as "unknown".
return_model	Logical. If TRUE, returns a list containing both predictions and the trained model. Default is FALSE.
...	Additional arguments passed to computeRankedMatrix.

Value

A data frame of predictions (by default), or a list with elements predictions and model if return_model = TRUE.

Examples

```
# Read in single-cell reference data
seu_sc <- readRDS(system.file("extdata", "seu_sc.rds",
```

```
    package = "RankMap"
))

# Read in Xenium spatial data
seu_xen <- readRDS(system.file("extdata", "seu_xen.rds",
    package = "RankMap"
))

# Predict cell type for spatial data using single-cell data as reference
pred_df <- RankMap(
    ref_data = seu_sc,
    ref_labels = seu_sc$cell_type,
    new_data = seu_xen
)
head(pred_df)
```

`sampleCellsByType` *Sample Cells by Cell Type with Minimum Representation*

Description

This function samples a specified total number of cells from a metadata table, ensuring that each cell type is represented by at least a minimum number of cells.

Usage

```
sampleCellsByType(cell_metadata, n_total_cells = 5000, min_per_type = 50)
```

Arguments

`cell_metadata`	A data frame containing at least two columns: `cell_id` and `cell_type`.
`n_total_cells`	Total number of cells to sample. Default is `5000`.
`min_per_type`	Minimum number of cells to sample from each `cell_type`. Default is `50`.

Value

A data frame of sampled cells with at least `min_per_type` cells per `cell_type`.

Examples

```
meta <- data.frame(
    cell_id = paste0("cell", 1:10000),
    cell_type = sample(c("T", "B", "Mac"), 10000, replace = TRUE)
)
set.seed(42)
sampled <- sampleCellsByType(meta,
    n_total_cells = 1000,
    min_per_type = 50
```

```
)
```

`topCellTypeGenes` *Get top expressed genes for each cell type*

Description

Identify the top `n` highly expressed genes for each cell type based on average expression across cells. This function is useful for summarizing representative genes from a reference dataset and can be optionally used to restrict features for downstream analysis.

Usage

```
topCellTypeGenes(data, cell_type, n = 50, genes = NULL, return_list = FALSE)
```

Arguments

`data`	A gene expression object. Supported inputs include `Seurat`, `SingleCellExperiment`, `SpatialExperiment`, or a matrix-like object. Expression values are extracted using `extractData()`.
`cell_type`	A vector of cell type labels corresponding to columns of `data`.
`n`	Integer. Number of top expressed genes to return for each cell type. Default is `50`.
`genes`	Optional character vector of gene names to restrict the analysis. Only genes present in `data` will be used.
`return_list`	Logical. If `TRUE`, return a list of top genes for each cell type. If `FALSE`, return a unique vector of genes across all cell types. Default is `FALSE`.

Details

For each cell type, genes are ranked by their average expression (computed using `Matrix::rowMeans`) across cells of that type. Cells with missing (`NA`) cell type labels are removed prior to computation.

Value

If `return_list = TRUE`, a named list where each element contains the top `n` genes for a cell type. Otherwise, a character vector of unique top genes across all cell types.

Examples

```
# Read in single-cell reference data
seu_sc <- readRDS(system.file("extdata", "seu_sc.rds",
    package = "RankMap"
))

# Get top genes across all cell types
```

```
top_genes <- topCellTypeGenes(
    data = seu_sc,
    cell_type = seu_sc$cell_type,
    n = 50
)

# Get top genes per cell type
top_list <- topCellTypeGenes(
    data = seu_sc,
    cell_type = seu_sc$cell_type,
    n = 50,
    return_list = TRUE
)
```

`trainRankModel` *Train Multinomial Rank-Based Model*

Description

This function trains a multinomial logistic regression model using ranked gene expression. Optionally performs cross-validation to select the optimal regularization parameter.

Usage

```
trainRankModel(
  data = NULL,
  labels = NULL,
  alpha = 0.1,
  cv = FALSE,
  nfolds = 5,
  ...
)
```

Arguments

`data`	A gene expression matrix with genes as rows and cells (or spatial spots) as columns. Can be a `Seurat` object, a `SummarizedExperiment` object, a dense numeric matrix, or a sparse `dgCMatrix`.
`labels`	A vector of cell type labels (one per column of `data`).
`alpha`	Elastic net mixing parameter. 1 = LASSO, 0 = Ridge. Default is `0.1`.
`cv`	Logical. If `TRUE`, performs cross-validation using `cv.glmnet`. Default is `FALSE`.
`nfolds`	Number of folds for cross-validation (only used if `cv = TRUE`). Default is `5`.
`...`	Additional arguments passed to `computeRankedMatrix`.

Value

A fitted `glmnet` or `cv.glmnet` model object.

See Also

computeRankedMatrix, predictRankModel

Examples

```
# Read in single-cell reference data
seu_sc <- readRDS(system.file("extdata", "seu_sc.rds",
    package = "RankMap"
))

# Extract normalized expression data
mat <- extractData(seu_sc)

# Train a model
set.seed(42)
model <- trainRankModel(mat, seu_sc$cell_type)

# Train a model with cross-validation
model <- trainRankModel(
    data = mat,
    labels = seu_sc$cell_type,
    cv = TRUE,
    nfolds = 3
)
```

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