Package: discoCVI (via r-universe)

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Type Package

Title Implementation of the DISCO Metric for Internal Clustering Evaluation

Version 0.2.1

Description Implementation of the DISCO (Density-based Internal Score for Clusterings with nOise) metric, a cluster validity index for evaluating density-based clustering results without ground truth labels. DISCO is the first index to explicitly assess the quality of noise point assignments in addition to cluster quality. It uses density-connectivity distance derived from a minimum spanning tree of the mutual-reachability graph, providing interpretable, bounded scores in [-1, 1]. Higher scores indicate better clustering. Based on Beer et al. (2025) <doi:10.48550/arXiv.2503.00127>.

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LinkingTo Rcpp

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BugReports https://github.com/aminentezari/discoCVI/issues

NeedsCompilation yes

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`compute_dc_distances` *Compute density-connectivity (DC) distances*

Description

The main entry point for constructing the DC-distance matrix used throughout the DISCO metric. The procedure is:

1. Compute core distances and build the minimum spanning tree of the mutual-reachability distances (see `calculate_reachability_distance`). Since version 0.2.0 the tree is built in compiled code with distances computed on the fly, so the mutual-reachability matrix is never stored.
2. Extract pairwise DC distances as minimax-path weights in the MST (`extract_dc_distances_from_mst`).

Note that the returned matrix has n^2 entries; `disco_samples` and `disco_score` do not need it and use far less memory.

Usage

```
compute_dc_distances(X, min_points = 5)
```

Arguments

`X`	A numeric matrix of shape $n \times p$, or a `data.frame` that will be coerced to a matrix.
`min_points`	A positive integer for the core-distance neighbourhood size. Default is `5`.

Value

A symmetric $n \times n$ numeric matrix of DC distances.

Examples

```
set.seed(1)
X <- matrix(rnorm(40), ncol = 2)
D <- compute_dc_distances(X, min_points = 5)
dim(D)   # 20 x 20
```

---

disco_samples *Per-sample DISCO scores*

Description

Computes a pointwise DISCO score for every observation in `X`. The score lies in $[-1, 1]$:

- Values close to 1 indicate a well-placed point (either tightly within its cluster or a noise point far from all clusters).
- Values close to 0 indicate borderline placement.
- Values close to -1 indicate a misplaced point (or a noise point that should belong to a cluster).

Four cases are handled:

1. **All noise** — every point labelled `-1`: all scores are `-1`.
2. **Single cluster with no noise** — all scores are `0`.
3. **One real cluster + noise** — cluster points are scored via `p_cluster`; noise points are scored via `p_noise`.
4. **Two or more clusters (optional noise)** — non-noise points use `p_cluster` on the non-noise sub-matrix; noise points use `p_noise`.

Since version 0.2.0 these quantities are computed from the merge tree of the mutual-reachability minimum spanning tree, without storing any $n \times n$ matrix: memory grows linearly with n (times the number of clusters), and the scores are identical to the previous matrix-based implementation up to floating-point rounding.

Usage

```
disco_samples(X, labels, min_points = 5)
```

Arguments

`X`	A numeric matrix ($n \times p$) or `data.frame`.
`labels`	An integer vector of length n containing cluster labels. Use `-1` to denote noise/outlier points.
`min_points`	A positive integer for the core-distance neighbourhood size. Default is `5`.

Value

A numeric vector of length n with per-point DISCO scores.

See Also

disco_score, p_cluster, p_noise

Examples

```
set.seed(42)
X <- matrix(rnorm(100), ncol = 2)
labels <- rep(c(0L, 1L), each = 25)
s <- disco_samples(X, labels)
hist(s, main = "Per-sample DISCO scores")
```

---

disco_score *Overall DISCO score*

Description

Returns the mean of the per-sample DISCO scores produced by disco_samples. This is the single-number summary of clustering quality used for model selection and comparison.

Usage

```
disco_score(X, labels, min_points = 5)
```

Arguments

X	A numeric matrix ($n \times p$) or data.frame.
labels	An integer vector of cluster labels (-1 for noise).
min_points	Positive integer; core-distance neighbourhood size. Default is 5.

Value

A single numeric value in $[-1, 1]$.

See Also

disco_samples

Examples

```
set.seed(42)
X <- matrix(rnorm(100), ncol = 2)
labels <- rep(c(0L, 1L), each = 25)
disco_score(X, labels)
```

p_cluster *Silhouette-like cluster scores using DC distances*

Description

Computes a silhouette coefficient for each non-noise point using the precomputed (or internally derived) DC-distance matrix rather than raw Euclidean distances. This matches the formula used by `sklearn.metrics.silhouette_samples` with `metric="precomputed"` (Python reference: `disco.py`, line 280):

$$s(i) = \frac{b(i) - a(i)}{\max(a(i),\, b(i))}$$

where $a(i)$ is the mean DC distance from i to all other points in the same cluster and $b(i)$ is the minimum over other clusters of the mean DC distance from i to that cluster. Points that form a singleton cluster score 0, as defined in the DISCO paper (and as in `silhouette_samples`); version 0.1.1 incorrectly gave them 1.

Usage

```
p_cluster(X, labels, min_points = 5, precomputed_dc_dists = FALSE)
```

Arguments

`X`	Either (a) a numeric matrix of raw data ($n \times p$) when `precomputed_dc_dists = FALSE`, or (b) a precomputed $n \times n$ DC-distance matrix when `precomputed_dc_dists = TRUE`.
`labels`	An integer vector of cluster labels of length n. Noise labels (`-1`) should not be present; pass only the non-noise subset.
`min_points`	Positive integer; used only when `precomputed_dc_dists = FALSE`. Default is `5`.
`precomputed_dc_dists`	Logical. If `TRUE`, `X` is treated as an already-computed DC-distance matrix; no further distances are computed. Default is `FALSE`.

Value

A numeric vector of length n with per-point silhouette-style scores in $[-1, 1]$.

See Also

`disco_samples`, `compute_dc_distances`

Examples

```
set.seed(7)
X <- matrix(rnorm(60), ncol = 2)
labels <- rep(c(0L, 1L, 2L), each = 10)
p_cluster(X, labels)
```

p_noise *Noise-point scores*

Description

Assigns a quality score to each point labelled as noise (`-1`). Two complementary sub-scores are computed and the element-wise minimum is taken as the final score:

p_{sparse} Measures whether the noise point is sparser (more peripheral in density) than the densest part of every real cluster. For cluster c, let M_c be the maximum core distance over all points in c. Then

$$p_{\text{sparse}}(i) = \min_c \frac{\text{core}_k(i) - M_c}{\max(\text{core}_k(i),\, M_c)}.$$

p_{far} Measures whether the noise point is far from every cluster in DC-distance space. For cluster c, let $d_{\min,c}(i)$ be the minimum DC distance from i to any point in c. Then

$$p_{\text{far}}(i) = \min_c \frac{d_{\min,c}(i) - M_c}{\max(d_{\min,c}(i),\, M_c)}.$$

Both sub-scores lie in $[-1, 1]$: positive means the noise point is legitimately sparse/far; negative means it is denser/closer than the cluster boundary and might be a misclassified inlier.

Usage

```
p_noise(X, labels, min_points = 5, dc_dists = NULL)
```

Arguments

`X`	A numeric matrix ($n \times p$) or `data.frame` of all points (including non-noise).
`labels`	An integer vector of length n; `-1` denotes noise.
`min_points`	Positive integer ≥ 2; core-distance neighbourhood size. Default is `5`.
`dc_dists`	Optional precomputed $n \times n$ DC-distance matrix. If `NULL` (default), it is computed internally.

Value

A named list with two numeric vectors, each of length equal to the number of noise points:

p_sparse Sparsity-based noise scores.

p_far DC-distance-based noise scores.

See Also

`disco_samples`

Examples

```
set.seed(3)
X      <- matrix(rnorm(60), ncol = 2)   # 30 rows x 2 cols
labels <- c(rep(0L, 10), rep(1L, 10), rep(-1L, 10))  # 30 labels
nr     <- p_noise(X, labels, min_points = 3)
str(nr)
```

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