

Package ‘dtwclust’

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Description Time series clustering along with optimized techniques related to the Dynamic Time Warping distance and its corresponding lower bounds. Implementations of partitional, hierarchical, fuzzy, k-Shape and TADPole clustering are available. Functionality can be easily extended with custom distance measures and centroid definitions. Implementations of DTW barycenter averaging and a distance based on global alignment kernels are also provided. Several cluster validity indices are included.

URL <https://github.com/asardaes/dtwclust>

BugReports <https://github.com/asardaes/dtwclust/issues>

License GPL-3

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'dtw-lb.R' 'dtw2.R' 'tsclust-family.R' 'tsclust-classes.R'
 'dtwclust-classes.R' 'dtwclust-methods.R' 'dtwclust.R'
 'fuzzy.R' 'globals-internal.R' 'lb-improved.R' 'lb-keogh.R'
 'partitional.R' 'reinterpolate.R' 'shape-extraction.R'
 'tsclust-controls.R' 'tsclust-methods.R' 'tsclust.R' 'tslist.R'
 'uciCT.R' 'zscore.R'

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dtwclust-package	<i>Time series clustering along with optimizations for the Dynamic Time Warping distance</i>
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Description

Time series clustering with a wide variety of strategies and a series of optimizations specific to the Dynamic Time Warping (DTW) distance and its corresponding lower bounds (LBs).

Details

Many of the algorithms implemented in this package are specifically tailored to DTW, hence its name. However, the main clustering function is flexible so that one can test many different clustering approaches, using either the time series directly, or by applying suitable transformations and then clustering in the resulting space. Other implementations included in the package provide some alternatives to DTW.

DTW is a dynamic programming algorithm that tries to find the optimum warping path between two series. Over the years, several variations have appeared in order to make the procedure faster or more efficient. Please refer to the included references for more information, especially Giorgino (2009), which is a good practical introduction.

Most optimizations require equal dimensionality, which means time series should have equal length. DTW itself does not require this, but it is relatively expensive to compute. Other distance definitions may be used, or series could be reinterpolated to a matching length (Ratanamahatana and Keogh 2004).

The main clustering function and entry point for this package is `tsclust()`, with a convenience wrapper for multiple tests in `compare_clusterings()`.

Please note the random number generator is set to L'Ecuyer-CMRG when **dtwclust** is attached in an attempt to preserve reproducibility. You are free to change this afterwards if you wish. See `base::RNGkind()`.

For more information, please read the included package vignette, which can be accessed by typing `vignette("dtwclust")`.

Note

This software package was developed independently of any organization or institution that is or has been associated with the author.

There are a couple of reasons why this package will **not** work if it is not attached (via `base::library()`). For the specifics, see below.

The **methods** package must be attached in order for some internal inheritance to work properly. This is usually done automatically by R, with `utils::Rscript()` being an exception. This is why this package is a dependency of **dtwclust**. Additionally, the included distance functions are registered with **proxy** during attachment.

Author(s)

Alexis Sarda-Espinosa

References

Please refer to the package vignette references.

See Also

`tsclust()`, `compare_clusterings()`, `proxy::dist()`, `dtw::dtw()`

as.matrix

as.matrix

Description

proxy exported a non-generic `as.matrix` function. This is to re-export the base version and add coercion methods for `pairdist` and `crossdist`.

Usage

```
as.matrix(x, ...)
```

Arguments

`x, ...` See `base::as.matrix()`.

See Also

`base::as.matrix()`

clusterSim	<i>Cluster Similarity Matrix</i>
------------	----------------------------------

Description

No longer supported directly in **dtwclust**.

Usage

```
## S4 method for signature 'dtwclust'
clusterSim(object, data = NULL, method = c("shadow",
      "centers"), symmetric = FALSE, ...)
```

Arguments

object, data, method, symmetric, ...
 See [flexclust::clusterSim\(\)](#).

See Also

[flexclust::clusterSim\(\)](#)

compare_clusterings	<i>Compare different clustering configurations</i>
---------------------	----------------------------------------------------

Description

Compare many different clustering algorithms with support for parallelization.

Usage

```
compare_clusterings(series = NULL, types = c("p", "h", "f", "t"), ...,
  configs = compare_clusterings_configs(types), seed = NULL,
  trace = FALSE, score.clus = function(...) stop("No scoring"),
  pick.clus = function(...) stop("No picking"), shuffle.configs = FALSE,
  return.objects = FALSE, packages = character(0L),
  .errorhandling = "stop")
```

Arguments

series	A list of series, a numeric matrix or a data frame. Matrices and data frames are coerced to a list row-wise.
types	Clustering types. It must be any combination of (possibly abbreviated): partitional, hierarchical, fuzzy, tadpole.
...	Further arguments for tsclust() , <code>score.clus</code> or <code>pick.clus</code> .

<code>configs</code>	The list of data frames with the desired configurations to run. See <code>pd_configs()</code> and <code>compare_clusterings_configs()</code> .
<code>seed</code>	Seed for random reproducibility.
<code>trace</code>	Logical indicating that more output should be printed to screen.
<code>score.clus</code>	A function that gets the list of results (and . . .) and scores each one. It may also be a named list of functions, one for each type of clustering. See Scoring section.
<code>pick.clus</code>	A function that to pick the best result. See Picking section.
<code>shuffle.configs</code>	Randomly shuffle the order of configs, which can be useful to balance load when using parallel computation.
<code>return.objects</code>	Logical indicating whether the objects returned by <code>tsclust()</code> should be given in the result.
<code>packages</code>	A character vector with the names of any packages needed for any functions used (distance, centroid, preprocessing, etc.). The name "dtwclust" is added automatically. Relevant for parallel computation.
<code>.errorhandling</code>	This will be passed to <code>foreach::foreach()</code> . See Parallel section below.

Details

This function calls `tsclust()` with different configurations and evaluates the results with the provided functions. Parallel support is included. See the examples.

Parameters specified in `configs` whose values are NA will be ignored automatically.

The scoring and picking functions are for convenience, if they are not specified, the scores and pick elements of the result will be NULL.

Value

A list with:

- `results`: A list of data frames with the flattened configs and the corresponding scores returned by `score.clus`.
- `scores`: The scores given by `score.clus`.
- `pick`: The object returned by `pick.clus`.
- `proc_time`: The measured execution time, using `base::proc.time()`.
- `seeds`: A list of lists with the random seeds computed for each configuration.

The cluster objects are also returned if `return.objects = TRUE`.

Parallel computation

The configurations for each clustering type can be evaluated in parallel with the **foreach** package. A parallel backend can be registered, e.g., with **doParallel**.

If the `.errorhandling` parameter is changed to "pass" and a custom `score.clus` function is used, said function should be able to deal with possible error objects.

If it is changed to "remove", it might not be possible to attach the scores to the results data frame, or it may be inconsistent. Additionally, if `return.objects` is `TRUE`, the names given to the objects might also be inconsistent.

Parallelization can incur a lot of deep copies of data when returning the cluster objects, since each one will likely contain a copy of `datalist`. If you want to avoid this, consider specifying `score.clus` and setting `return.objects` to `FALSE`.

Scoring

The clustering results are organized in a *list of lists* in the following way (where only applicable types exist; first-level list names in bold):

- **partitional** - list with
 - Clustering results from first partitional config
 - etc.
- **hierarchical** - list with
 - Clustering results from first hierarchical config
 - etc.
- **fuzzy** - list with
 - Clustering results from first fuzzy config
 - etc.
- **tadpole** - list with
 - Clustering results from first tadpole config
 - etc.

If `score.clus` is a function, it will be applied to the available partitional, hierarchical, fuzzy and/or tadpole results via:

```
scores <- lapply(list_of_lists, score.clus, ...)
```

Otherwise, `score.clus` should be a list of functions with the same names as the list above, so that `score.clus$partitional` is used to score `list_of_lists$partitional` and so on (via [base::Map\(\)](#)).

Therefore, the scores returned shall always be a list of lists with first-level names as above.

Picking

If `return.objects` is `TRUE`, the scores and the list of clustering results are given to `pick.clus` as first and second arguments respectively, followed by `...` Otherwise, `pick.clus` will receive only the scores and the contents of `...` (since the results will not be returned by the preceding step).

Limitations

Note that the configurations returned by the helper functions assign special names to preprocessing/distance/centroid arguments, and these names are used internally to recognize them.

If some of these arguments are more complicated (e.g. matrices) and should *not* be expanded, consider passing them directly via the ellipsis (...) instead of using `pd_c_configs()`. This assumes that said arguments can be passed to all functions without affecting their results.

The distance matrices (if calculated) are not re-used across configurations. Given the way the configurations are created, this shouldn't matter, because clusterings with arguments that can use the same distance matrix are already grouped together by `compare_clusterings_configs()` and `pd_c_configs()`.

Author(s)

Alexis Sarda-Espinosa

See Also

`compare_clusterings_configs()`, `tsclust()`

Examples

```
## Fuzzy preprocessing: calculate autocorrelation up to 50th lag
acf_fun <- function(dat, ...) {
  lapply(dat, function(x) {
    as.numeric(acf(x, lag.max = 50, plot = FALSE)$acf)
  })
}

## Define overall configuration
cfs <- compare_clusterings_configs(
  types = c("p", "h", "f", "t"),
  k = 19L:20L,
  controls = list(
    partitional = partitional_control(
      iter.max = 30L,
      nrep = 1L
    ),
    hierarchical = hierarchical_control(
      method = "all"
    ),
    fuzzy = fuzzy_control(
      ## notice the vector
      fuzziness = c(2, 2.5),
      iter.max = 30L
    ),
    tadpole = tadpole_control(
      ## notice the vectors
      dc = c(1.5, 2),
      window.size = 19L:20L
    )
  )
}
```

```

    ),
    preprocs = pdc_configs(
      type = "preproc",
      ## shared
      none = list(),
      zscore = list(center = c(FALSE)),
      ## only for fuzzy
      fuzzy = list(
        acf_fun = list()
      ),
      ## only for tadpole
      tadpole = list(
        reinterpolate = list(new.length = 205L)
      ),
      ## specify which should consider the shared ones
      share.config = c("p", "h")
    ),
    distances = pdc_configs(
      type = "distance",
      sbd = list(),
      fuzzy = list(
        L2 = list()
      ),
      share.config = c("p", "h")
    ),
    centroids = pdc_configs(
      type = "centroid",
      partitional = list(
        pam = list()
      ),
      ## special name 'default'
      hierarchical = list(
        default = list()
      ),
      fuzzy = list(
        fcmdd = list()
      ),
      tadpole = list(
        default = list(),
        shape_extraction = list(znorm = TRUE)
      )
    )
  )
)

## Number of configurations is returned as attribute
num_configs <- sapply(cfgs, attr, which = "num.configs")
cat("\nTotal number of configurations without considering optimizations:",
    sum(num_configs),
    "\n\n")

## Define evaluation function based on CVI: Variation of Information
score_fun <- function(obj_list, ...) {
  sapply(obj_list, function(obj) {

```

```

        cvi(obj@cluster, CharTrajLabels, type = "VI")
    })
}

## Function that chooses best result
pick_fun <- function(scores, obj_lists, ...) {
    best_considering_type <- sapply(scores, which.min)
    best_overall <- which.min(mapply(scores, best_considering_type,
                                     FUN = function(score, id) { score[id] })))

    best_obj <- obj_lists[[best_overall]][[best_considering_type[best_overall]]]

    ## return
    best_obj
}

# =====
# Short run with only fuzzy clustering
# =====

comparison_short <- compare_clusterings(CharTraj, types = c("f"), configs = cfigs,
                                         seed = 293L, trace = TRUE,
                                         score.clus = score_fun, pick.clus = pick_fun,
                                         return.objects = TRUE)

## Not run:
# =====
# Parallel run with all comparisons
# =====

require(doParallel)
registerDoParallel(cl <- makeCluster(detectCores()))

comparison_long <- compare_clusterings(CharTraj, types = c("p", "h", "f", "t"),
                                       configs = cfigs,
                                       seed = 293L, trace = TRUE,
                                       score.clus = score_fun,
                                       pick.clus = pick_fun,
                                       return.objects = TRUE)

# -----
# Using all external CVIs and majority vote
# -----

score_external <- function(obj_list, ...) {
    scores <- lapply(obj_list, function(obj) {
        indices <- cvi(obj@cluster, CharTrajLabels, type = "external")

        ## invert VI to consider maximization
        indices["VI"] <- 1 / indices["VI"]

        ## return
        indices
    })
}

```

```

    })

    ## return
    do.call(rbind, scores)
  }

  pick_majority <- function(scores, obj_lists, ...) {
    majority <- function(x) {
      ux <- unique(x)
      ux[which.max(tabulate(match(x, ux)))]
    }

    best_considering_type <- sapply(scores, function(score) {
      best_by_cvi <- apply(score, 2L, which.max)
      majority(best_by_cvi)
    })

    best_cvis_overall <- do.call(rbind,
                                mapply(scores, best_considering_type,
                                        SIMPLIFY = FALSE,
                                        FUN = function(score, row_id) {
                                          score[row_id, , drop = FALSE]
                                        },
                                        ))

    best_overall <- majority(apply(best_cvis_overall, 2L, which.max))

    best_obj <- obj_lists[[best_overall]][[best_considering_type[best_overall]]]

    ## to find config later, see 'best config' below
    attr(best_obj, "config_id") <- c(best_overall,
                                     best_considering_type[best_overall])

    ## return
    best_obj
  }

  comparison_majority <- compare_clusterings(CharTraj, types = c("p", "h", "f", "t"),
                                             configs = cfigs,
                                             seed = 84L, trace = TRUE,
                                             score.clus = score_external,
                                             pick.clus = pick_majority,
                                             return.objects = TRUE)

  plot(comparison_majority$pick)

  ## best config
  config_id <- attr(comparison_majority$pick, "config_id")
  print(comparison_majority$results[[config_id[1L]][[config_id[2L], , drop = FALSE]])

  stopCluster(cl); registerDoSEQ()

  # =====
  # A run with only partitional clusterings

```

```

# =====
p_cfgs <- compare_clusterings_configs(types = "p", k = 19L:21L,
                                     controls = list(
                                       partitional = partitional_control(
                                         iter.max = 20L,
                                         nrep = 8L
                                       )
                                     ),
                                     preprocs = pdc_configs(
                                       "preproc",
                                       none = list(),
                                       zscore = list(center = c(FALSE, TRUE))
                                     ),
                                     distances = pdc_configs(
                                       "distance",
                                       sbd = list(),
                                       dtw_basic = list(window.size = 19L:20L,
                                                         norm = c("L1", "L2")),
                                       gak = list(window.size = 19L:20L,
                                                  sigma = 100)
                                     ),
                                     centroids = pdc_configs(
                                       "centroid",
                                       partitional = list(
                                         pam = list(),
                                         shape = list()
                                       )
                                     )
                                     )

# Remove redundant (shape centroid always uses zscore preprocessing)
id_redundant <- p_cfgs$partitional$preproc == "none" &
  p_cfgs$partitional$centroid == "shape"
p_cfgs$partitional <- p_cfgs$partitional[!id_redundant, ]

# LONG! 20 minutes or so, sequentially
comparison_partitional <- compare_clusterings(CharTraj, types = "p",
                                              configs = p_cfgs,
                                              seed = 32903L, trace = TRUE,
                                              score.clus = score_fun,
                                              pick.clus = pick_fun,
                                              shuffle.configs = TRUE,
                                              return.objects = TRUE)

## End(Not run)

```

compare_clusterings_configs

Create clustering configurations.

Description

Create configurations for `compare_clusterings()`

Usage

```
compare_clusterings_configs(types = c("p", "h", "f"), k = 2L,
  controls = NULL, preprocs = pdc_configs("preproc", none = list()),
  distances = pdc_configs("distance", dtw_basic = list()),
  centroids = pdc_configs("centroid", default = list()))
```

Arguments

types	Clustering types. It must be any combination of (possibly abbreviated): partitional, hierarchical, fuzzy, tadpole.
k	A numeric vector with one or more elements specifying the number of clusters to test.
controls	A named list of tsclust-controls . NULL means defaults. See details.
preprocs	Preprocessing configurations. See details.
distances	Distance configurations. See details.
centroids	Centroid configurations. See details.

Details

This function uses `base::expand.grid()` and `base::merge()`.

Preprocessing, distance and centroid configurations are specified with the helper function `pdc_configs()`, refer to the examples in `compare_clusterings()` to see how this is used.

The controls list may be specified with the usual [tsclust-controls](#) functions. The names of the list must correspond to "partitional", "hierarchical", "fuzzy" or "tadpole" clustering. Again, please refer to the examples in `compare_clusterings()`.

Value

A list for each clustering type, each of which includes a data frame with the computed and merged configurations. Each data frame has an extra attribute `num.configs` specifying the number of configurations.

compute_envelope	<i>Time series warping envelopes</i>
------------------	--------------------------------------

Description

This function computes the envelopes for DTW lower bound calculations with a Sakoe-Chiba band for a given univariate time series using the streaming algorithm proposed by Lemire (2009).

Usage

```
compute_envelope(x, window.size, error.check = TRUE)
```

```
compute_envelop(x, window.size, error.check = TRUE)
```

Arguments

<code>x</code>	A univariate time series.
<code>window.size</code>	Window size for envelope calculation. See details.
<code>error.check</code>	Logical indicating whether the function should try to detect inconsistencies and give more informative errors messages. Also used internally to avoid repeating checks.

Details

The windowing constraint uses a centered window. The calculations expect a value in `window.size` that represents the distance between the point considered and one of the edges of the window. Therefore, if, for example, `window.size = 10`, the warping for an observation x_i considers the points between x_{i-10} and x_{i+10} , resulting in $10(2) + 1 = 21$ observations falling within the window.

Value

A list with two elements (lower and upper envelopes): lower and upper.

Note

This envelope is calculated assuming a Sakoe-Chiba constraint for DTW.

References

Lemire D (2009). "Faster retrieval with a two-pass dynamic-time-warping lower bound ." *Pattern Recognition*, **42**(9), pp. 2169 - 2180. ISSN 0031-3203, <http://dx.doi.org/10.1016/j.patcog.2008.11.030>, <http://www.sciencedirect.com/science/article/pii/S0031320308004925>.

Examples

```
data(uciCT)

H <- compute_envelope(CharTraj[[1L]], 18L)

matplot(do.call(cbind, H), type = "l", col = 2:3)
lines(CharTraj[[1L]])
```

create_dtwclust	<i>Create formal dtwclust objects</i>
-----------------	---------------------------------------

Description

Deprecated helper function to manually create formal [dtwclust](#) objects

Usage

```
create_dtwclust(..., override.family = TRUE)
```

Arguments

... Any valid slots of [dtwclust](#).
 override.family Attempt to substitute the default family with one that conforms to the provided elements? See details.

Details

Please see the initialize section in [tsclusters-methods](#) for the new objects..

Value

A [dtwclust](#) object.

cvi	<i>Cluster validity indices</i>
-----	---------------------------------

Description

Compute different cluster validity indices (CVIs) of a given cluster partition, using the clustering distance measure and centroid function if applicable.

Usage

```
cvi(a, b = NULL, type = "valid", ..., log.base = 10)

## S4 method for signature 'dtwclust'
cvi(a, b = NULL, type = "valid", ..., log.base = 10)

## S4 method for signature 'PartitionalTSClusters'
cvi(a, b = NULL, type = "valid", ...,
    log.base = 10)

## S4 method for signature 'HierarchicalTSClusters'
cvi(a, b = NULL, type = "valid", ...,
    log.base = 10)
```

Arguments

a	An object returned by the <code>dtwclust()</code> or <code>tsclust()</code> function, or a vector that can be coerced to integers which indicate the cluster memberships.
b	If needed, a vector that can be coerced to integers which indicate the cluster memberships. The ground truth (if known) should be provided here.
type	Character vector indicating which indices are to be computed. See supported values below.
...	Arguments to pass to and from other methods.
log.base	Base of the logarithm to be used in the calculation of VI.

Details

Clustering is commonly considered to be an unsupervised procedure, so evaluating its performance can be rather subjective. However, a great amount of effort has been invested in trying to standardize cluster evaluation metrics by using cluster validity indices (CVIs).

CVIs can be classified as internal, external or relative depending on how they are computed. Focusing on the first two, the crucial difference is that internal CVIs only consider the partitioned data and try to define a measure of cluster purity, whereas external CVIs compare the obtained partition to the correct one. Thus, external CVIs can only be used if the ground truth is known. Each index defines their range of values and whether they are to be minimized or maximized. In many cases, these CVIs can be used to evaluate the result of a clustering algorithm regardless of how the clustering works internally, or how the partition came to be.

Knowing which CVI will work best cannot be determined a priori, so they should be tested for each specific application. Usually, many CVIs are utilized and compared to each other, maybe using a majority vote to decide on a final result. Furthermore, it should be noted that many CVIs perform additional distance calculations when being computed, which can be very considerable if using DTW.

Note that even though a fuzzy partition can be changed into a crisp one, making it compatible with many of the existing CVIs, there are also fuzzy CVIs tailored specifically to fuzzy clustering, and these may be more suitable in those situations, but have not been implemented here yet.

Value

The chosen CVIs

External CVIs

The first 4 CVIs are calculated via `flexclust::comPart()`, so please refer to that function.

- "RI": Rand Index (to be maximized).
- "ARI": Adjusted Rand Index (to be maximized).
- "J": Jaccard Index (to be maximized).
- "FM": Fowlkes-Mallows (to be maximized).
- "VI": Variation of Information (Meila (2003); to be minimized).

Internal CVIs

The indices marked with an exclamation mark (!) calculate (or re-use if already available) the whole distance matrix between the series in the data. If you were trying to avoid this in the first place, then these CVIs might not be suitable for your application.

The indices marked with a question mark (?) depend on the extracted centroids, so bear that in mind if a hierarchical procedure was used and/or the centroid function has associated randomness (such as `shape_extraction()` with series of different length).

The indices marked with a tilde (~) require the calculation of a global centroid. Since `DBA()` and `shape_extraction()` (for series of different length) have some randomness associated, these indices might not be appropriate for those centroids.

- "Sil" (!): Silhouette index (Arbelaitz et al. (2013); to be maximized).
- "D" (!): Dunn index (Arbelaitz et al. (2013); to be maximized).
- "COP" (!): COP index (Arbelaitz et al. (2013); to be minimized).
- "DB" (?): Davies-Bouldin index (Arbelaitz et al. (2013); to be minimized).
- "DBstar" (?): Modified Davies-Bouldin index (DB*) (Kim and Ramakrishna (2005); to be minimized).
- "CH" (~): Calinski-Harabasz index (Arbelaitz et al. (2013); to be maximized).
- "SF" (~): Score Function (Saitta et al. (2007); to be maximized).

Additionally

- "valid": Returns all valid indices depending on the type of a and whether b was provided or not.
- "internal": Returns all internal CVIs. Only supported for `dtwclust` and `TSClusters` objects.
- "external": Returns all external CVIs. Requires b to be provided.

Note

In the original definition of many internal CVIs, the Euclidean distance and a mean centroid was used. The implementations here change this, making use of whatever distance/centroid was chosen during clustering.

The formula for the SF index in Saitta et al. (2007) does not correspond to the one in Arbelaitz et al. (2013). The one specified in the former is used here.

References

- Arbelaitz, O., Gurrutxaga, I., Muguerza, J., Perez, J. M., & Perona, I. (2013). An extensive comparative study of cluster validity indices. *Pattern Recognition*, 46(1), 243-256.
- Kim, M., & Ramakrishna, R. S. (2005). New indices for cluster validity assessment. *Pattern Recognition Letters*, 26(15), 2353-2363.
- Meila, M. (2003). Comparing clusterings by the variation of information. In *Learning theory and kernel machines* (pp. 173-187). Springer Berlin Heidelberg.
- Saitta, S., Raphael, B., & Smith, I. F. (2007). A bounded index for cluster validity. In *International Workshop on Machine Learning and Data Mining in Pattern Recognition* (pp. 174-187). Springer Berlin Heidelberg.

DBA

*DTW Barycenter Averaging***Description**

A global averaging method for time series under DTW (Petitjean, Ketterlin and Gancarski 2011).

Usage

```
DBA(X, centroid = NULL, ..., window.size = NULL, norm = "L1",
    max.iter = 20L, delta = 0.001, error.check = TRUE, trace = FALSE,
    gcm = NULL, mv.ver = "by-variable")
```

Arguments

<code>X</code>	A matrix or data frame where each row is a time series, or a list where each element is a time series. Multivariate series should be provided as a list of matrices where time spans the rows and the variables span the columns of each matrix.
<code>centroid</code>	Optionally, a time series to use as reference. Defaults to a random series of <code>X</code> if <code>NULL</code> . For multivariate series, this should be a matrix with the same characteristics as the matrices in <code>X</code> .
<code>...</code>	Further arguments for <code>dtw_basic()</code> . However, the following are already pre-specified: <code>window.size</code> , <code>norm</code> (passed along), and <code>backtrack</code> .
<code>window.size</code>	Window constraint for the DTW calculations. <code>NULL</code> means no constraint. A slanted band is used by default.
<code>norm</code>	Norm for the local cost matrix of DTW. Either "L1" for Manhattan distance or "L2" for Euclidean distance.
<code>max.iter</code>	Maximum number of iterations allowed.
<code>delta</code>	At iteration <code>i</code> , if <code>all(abs(centroid_{i} - centroid_{i-1}) < delta)</code> , convergence is assumed.
<code>error.check</code>	Logical indicating whether the function should try to detect inconsistencies and give more informative errors messages. Also used internally to avoid repeating checks.
<code>trace</code>	If <code>TRUE</code> , the current iteration is printed to output.
<code>gcm</code>	Optional matrix to pass to <code>dtw_basic()</code> (for the case when <code>backtrack = TRUE</code>). To define the matrix size, it should be assumed that <code>x</code> is the <i>longest</i> series in <code>X</code> , and <code>y</code> is the centroid if provided or <code>x</code> otherwise.
<code>mv.ver</code>	Multivariate version to use. See below.

Details

This function tries to find the optimum average series between a group of time series in DTW space. Refer to the cited article for specific details on the algorithm.

If a given series reference is provided in `centroid`, the algorithm should always converge to the same result provided the elements of `X` keep the same values, although their order may change.

The windowing constraint uses a centered window. The calculations expect a value in `window.size` that represents the distance between the point considered and one of the edges of the window. Therefore, if, for example, `window.size = 10`, the warping for an observation x_i considers the points between x_{i-10} and x_{i+10} , resulting in $10(2) + 1 = 21$ observations falling within the window.

Value

The average time series.

Multivariate series

There are currently 2 versions of DBA implemented for multivariate series:

- If `mv.ver = "by-variable"`, then each variable of each series in `X` and `centroid` are extracted, and the univariate version of the algorithm is applied to each set of variables, binding the results by column. Therefore, the DTW backtracking is different for each variable.
- If `mv.ver = "by-series"`, then all variables are considered at the same time, so the DTW backtracking is computed based on each multivariate series as a whole. This version was implemented in version 4.0.0 of **dtwclust**, and it might be faster.

Note

The indices of the DTW alignment are obtained by calling `dtw_basic()` with `backtrack = TRUE`.

References

Petitjean F, Ketterlin A and Gancarski P (2011). "A global averaging method for dynamic time warping, with applications to clustering." *Pattern Recognition*, **44**(3), pp. 678 - 693. ISSN 0031-3203, <http://dx.doi.org/10.1016/j.patcog.2010.09.013>, <http://www.sciencedirect.com/science/article/pii/S003132031000453X>.

Examples

```
# Sample data
data(uciCT)

# Obtain an average for the first 5 time series
dtw_avg <- DBA(CharTraj[1:5], CharTraj[[1]], trace = TRUE)

# Plot
matplot(do.call(cbind, CharTraj[1:5]), type = "l")
points(dtw_avg)
```

```
# Change the provided order
dtw_avg2 <- DBA(CharTraj[5:1], CharTraj[[1]], trace = TRUE)

# Same result?
all(dtw_avg2 == dtw_avg2)
```

Distmat-class

Distance matrix

Description

Reference class that is used internally for PAM centroids when both `pam.precompute` and `pam.sparse` are FALSE (see [tsclust-controls](#)).

Fields

`distmat` A distance matrix.
`series` Time series list.
`distfun` The distance function to calculate the distance matrix.
`dist_args` Arguments for the distance function.
`id_cent` Indices of the centroids (if any).

Methods

`initialize(..., distmat, series, distance, control, error.check = TRUE)` Initialization based on needed parameters

Distmat-generics

Generics for Distmat

Description

Generics with methods for [Distmat](#).

Usage

```
## S4 method for signature 'Distmat,ANY,ANY,ANY'
x[i, j, ..., drop = TRUE]
```

Arguments

x	A Distmat object.
i	Row indices.
j	Column indices.
...	Ignored.
drop	Logical to drop dimensions after subsetting.

Details

Accessing matrix elements with `[]` first calculates the values if necessary.

dtw2	<i>DTW distance with L2 norm</i>
------	----------------------------------

Description

Wrapper for the `dtw::dtw()` function using L2 norm for both the local cost matrix (LCM) creation as well as the final cost aggregation step.

Usage

```
dtw2(x, y, ...)
```

Arguments

x, y	A time series. A multivariate series should have time spanning the rows and variables spanning the columns.
...	Further arguments for <code>dtw::dtw()</code> .

Details

The L-norms are used in two different steps by the DTW algorithm. First when creating the LCM, where the element (i, j) of the matrix is computed as the L-norm of $x_i^v - y_j^v$ for all variables v . Note that this means that, in case of multivariate series, they must have the same number of variables, and that univariate series will produce the same LCM regardless of the L-norm used. After the warping path is found by DTW, the final distance is calculated as the L-norm of all (i, j) elements of the LCM that fall on the warping path.

The `dtw::dtw()` function allows changing the norm by means of its `dist.method` parameter, but it only uses it when creating the LCM, and not when calculating the final aggregated cost, i.e. the DTW distance.

This wrapper simply returns the appropriate DTW distance using L2 norm (Euclidean norm).

The windowing constraint uses a centered window. The calculations expect a value in `window.size` that represents the distance between the point considered and one of the edges of the window. Therefore, if, for example, `window.size = 10`, the warping for an observation x_i considers the points between x_{i-10} and x_{i+10} , resulting in $10(2) + 1 = 21$ observations falling within the window.

Value

An object of class `dtw`.

dtwclust

Time series clustering

Description

This is the **deprecated** function to perform time series clustering. See [tsclust\(\)](#) for the new interface.

Usage

```
dtwclust(data = NULL, type = "partitional", k = 2L, method = "average",
  distance = "dtw_basic", centroid = "pam", preproc = NULL, dc = NULL,
  control = NULL, seed = NULL, distmat = NULL, ...)
```

Arguments

<code>data</code>	A list of series, a numeric matrix or a data frame. Matrices and data frames are coerced row-wise.
<code>type</code>	What type of clustering method to use: "partitional", "hierarchical", "tadpole" or "fuzzy".
<code>k</code>	Number of desired clusters. It may be a numeric vector with different values.
<code>method</code>	Character vector with one or more linkage methods to use in hierarchical procedures (see stats::hclust()) or a function that performs hierarchical clustering based on distance matrices (e.g. cluster::diana()). See Hierarchical section for more details.
<code>distance</code>	A supported distance from proxy::dist() (see Distance section). Ignored for <code>type = "tadpole"</code> .
<code>centroid</code>	Either a supported string or an appropriate function to calculate centroids when using partitional or prototypes for hierarchical/tadpole methods. See Centroid section.
<code>preproc</code>	Function to preprocess data. Defaults to zscore() <i>only</i> if <code>centroid = "shape"</code> , but will be replaced by a custom function if provided. See Preprocessing section.
<code>dc</code>	Cutoff distance for the TADPole() algorithm.
<code>control</code>	Named list of parameters or <code>dtwclustControl</code> object for clustering algorithms. See dtwclustControl . NULL means defaults.
<code>seed</code>	Random seed for reproducibility.
<code>distmat</code>	If a cross-distance matrix is already available, it can be provided here so it's re-used. Only relevant if <code>centroid = "pam"</code> or <code>type = "hierarchical"</code> . See examples.
<code>...</code>	Additional arguments to pass to proxy::dist() or a custom function (preprocessing, centroid, etc.)

Details

Partitional and fuzzy clustering procedures use a custom implementation. Hierarchical clustering is done with `stats::hclust()`. TADPole clustering uses the `TADPole()` function. Specifying `type = "partitional"`, `distance = "sbd"` and `centroid = "shape"` is equivalent to the k-Shape algorithm (Paparrizos and Gravano 2015).

The data may be a matrix, a data frame or a list. Matrices and data frames are coerced to a list, both row-wise. Only lists can have series with different lengths or multiple dimensions. Most of the optimizations require series to have the same length, so consider reinterpolating them to save some time (see Ratanamahatana and Keogh 2004; `reinterpolate()`). No missing values are allowed.

In the case of multivariate time series, they should be provided as a list of matrices, where time spans the rows of each matrix and the variables span the columns. At the moment, only DTW, DTW2 and GAK support such series, which means only partitional and hierarchical procedures using those distances will work. You can of course create your own custom distances. All included centroid functions should work with the aforementioned format, although shape is **not** recommended. Note that the plot method will simply append all dimensions (columns) one after the other.

Several parameters can be adjusted with the control argument. See `dtwclustControl`. In the following sections, elements marked with an asterisk (*) are those that can be adjusted with this argument.

Value

An object with formal class `dtwclust`.

If `control@nrep > 1` and a partitional procedure is used, `length(method) > 1` and hierarchical procedures are used, or `length(k) > 1`, a list of objects is returned.

Author(s)

Alexis Sarda-Espinosa

References

Please refer to the package vignette references.

dtwclust-class

Class definition for dtwclust

Description

Deprecated S4 class.

Details

Please refer to `TSClusters` for the new class.

If you want to transform a `dtwclust-class` object to `TSClusters`, just use:

```
as(dtwclust_obj, "TSClusters")
```

although it may not work perfectly.

Slots

call The function call.
control An object of class [dtwclustControl](#).
family An object of class [dtwclustFamily](#).
distmat If computed, the cross-distance matrix.
k Integer indicating the number of desired clusters.
cluster Integer vector indicating which cluster a series belongs to (crisp partition). For fuzzy clustering, this is based on **distance**, not on **fcluster**. For hierarchical, this is obtained by calling [stats::cutree\(\)](#) with the given value of **k**.
fcluster Numeric matrix that contains membership of fuzzy clusters. It has one row for each series and one column for each cluster. The rows must sum to 1. Only relevant for fuzzy clustering.
iter The number of iterations used.
converged A logical indicating whether the function converged.
clusinfo A data frame with two columns: **size** indicates the number of series each cluster has, and **av_dist** indicates, for each cluster, the average distance between series and their respective centroids (crisp partition).
centroids A list with the centroid time series.
cldist A column vector with the distance between each series in the data and its corresponding centroid (crisp partition).
type A string indicating one of the supported clustering types of [dtwclust\(\)](#).
method A string indicating which hierarchical method was used.
distance A string indicating the distance used.
centroid A string indicating the centroid used.
preproc A string indicating the preprocessing used.
datalist The provided data in the form of a list, where each element is a time series.
proctime Time during function execution, as measured with [base::proc.time\(\)](#).
dots The contents of the original call's ellipsis (...).

dtwclust-deprecated *Deprecated functionality in **dtwclust***

Description

The following functions and/or classes are deprecated and will be eventually removed:

- [dtwclust\(\)](#) - see [tsclust\(\)](#)
- [dtwclustFamily](#) - see [tsclustFamily](#)
- [dtwclustControl](#) - see [tsclust-controls](#)
- [dtwclust](#) - see [TSClusters](#)

- [dtwclust-methods](#) - see [tsclusters-methods](#)
- [randIndex\(\)](#) - see [cvi\(\)](#)
- [clusterSim\(\)](#)
- [create_dtwclust\(\)](#) - see [tsclusters-methods](#)
- [compute_envelop\(\)](#) - see [compute_envelope\(\)](#)

dtwclust-methods

Methods for dtwclust

Description

Deprecated methods associated with [dtwclust](#) objects.

Usage

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

## S3 method for class 'dtwclust'
update(object, ..., evaluate = TRUE)

## S4 method for signature 'dtwclust'
update(object, ..., evaluate = TRUE)

## S3 method for class 'dtwclust'
predict(object, newdata = NULL, ...)

## S4 method for signature 'dtwclust'
predict(object, newdata = NULL, ...)

## S3 method for class 'dtwclust'
plot(x, y, ..., clus = seq_len(x@k), labs.arg = NULL,
      data = NULL, time = NULL, plot = TRUE, type = NULL)

## S4 method for signature 'dtwclust,missing'
plot(x, y, ..., clus = seq_len(x@k),
      labs.arg = NULL, data = NULL, time = NULL, plot = TRUE, type = NULL)
```

Arguments

object, x	An object of class dtwclust as returned by dtwclust() .
...	For plot, further arguments to pass to ggplot2::geom_line() for the plotting of the <i>cluster centroids</i> , or to stats::plot.hclust() . See details. For update, any supported argument. Otherwise ignored.
evaluate	Logical. Defaults to TRUE and evaluates the updated call, which will result in a new dtwclust object. Otherwise, it returns the unevaluated call.

newdata	New data to be assigned to a cluster. It can take any of the supported formats of dtwclust() . Note that for multivariate series, this means that it must be a list of matrices, even if the list has only one element.
y	Ignored.
clus	A numeric vector indicating which clusters to plot.
labs.arg	Arguments to change the title and/or axis labels. See ggplot2::labs() for more information
data	Optionally, the data in the same format as it was provided to dtwclust() .
time	Optional values for the time axis. If series have different lengths, provide the time values of the longest series.
plot	Logical flag. You can set this to FALSE in case you want to save the ggplot object without printing anything to screen
type	What to plot. NULL means default. See details.

Details

Please refer to [tsclusters-methods](#) for the updated versions.

dtwclustControl-class *Class definition for dtwclustControl*

Description

Deprecated S4 class with several control parameters used in [dtwclust\(\)](#).

Details

Please refer to [tsclust-controls](#) for the new interfaces.

Slots

window.size Integer or NULL. Window constraint for GAK, DTW, DBA and LB calculations. NULL means no constraint.
 norm Character. Pointwise distance for DTW, DBA and the LBs. Either "L1" for Manhattan distance or "L2" for Euclidean. Ignored for distance = "DTW2" (which always uses "L2").
 delta Numeric. Convergence criterion for [DBA\(\)](#) centroids and fuzzy clustering.
 trace Logical flag. If TRUE, more output regarding the progress is printed to screen.
 save.data Return a "copy" of the data in the returned object? Because of the way R handles things internally, all copies should point to the same memory address.
 symmetric Logical flag. Is the distance function symmetric? In other words, is $\text{dist}(x,y) == \text{dist}(y,x)$? If TRUE, only half the distance matrix needs to be computed. Only relevant for PAM centroids and hierarchical clustering. Overridden if the function detects an invalid user-provided value.

`packages` Character vector with the names of any packages required for custom proxy functions. See Parallel Computing section in `dtwclust()`. Since the distance entries are re-registered in each parallel worker if needed, this slot is probably useless, but just in case.

`dba.iter` Integer. Maximum number of iterations for `DBA()` centroids.

`pam.precompute` Logical flag. Precompute the whole distance matrix once and reuse it on each iteration if using PAM centroids. Otherwise calculate distances at every iteration.

`fuzziness` Numeric. Exponent used for fuzzy clustering. Commonly termed m in the literature.

`iter.max` Integer. Maximum number of allowed iterations for partitional/fuzzy clustering.

`nrep` Integer. How many times to repeat clustering with different starting points. See section Repetitions in `dtwclust()`.

Common parameters

- `window.size` = NULL
- `norm` = "L1"
- `delta` = 1e-3
- `trace` = FALSE
- `save.data` = TRUE
- `symmetric` = FALSE
- `packages` = `character(0)`

Only for partitional procedures

- `dba.iter` = 15L
- `pam.precompute` = TRUE

Only for fuzzy clustering

- `fuzziness` = 2

For both partitional and fuzzy

- `iter.max` = 100L
- `nrep` = 1L

dtwclustFamily-class *Class definition for dtwclustFamily*

Description

Deprecated S4 class with a family of functions used in `dtwclust()`.

Details

Please refer to `tsclustFamily` for the new class.

Slots

`dist` The function to calculate the distance matrices.
`allcent` The function to calculate centroids on each iteration.
`cluster` The function used to assign a series to a cluster.
`preproc` The function used to preprocess the data (relevant for `stats::predict()`).

dtw_basic *Basic DTW distance*

Description

This is a custom implementation of the DTW algorithm without all the functionality included in `dtw::dtw()`. Because of that, it should be slightly faster, while still supporting the most common options.

Usage

```
dtw_basic(x, y, window.size = NULL, norm = "L1",
  step.pattern = symmetric2, backtrack = FALSE, normalize = FALSE, ...,
  gcm = NULL, error.check = TRUE)
```

Arguments

<code>x, y</code>	Time series. Multivariate series must have time spanning the rows and variables spanning the columns.
<code>window.size</code>	Size for slanted band window. NULL means no constraint.
<code>norm</code>	Norm for the DTW calculation, "L1" for Manhattan or "L2" for Euclidean.
<code>step.pattern</code>	Step pattern for DTW. Only <code>symmetric1</code> or <code>symmetric2</code> supported here. Note that these are <i>not</i> characters. See <code>dtw::stepPattern</code> .
<code>backtrack</code>	Also compute the warping path between series? See details.
<code>normalize</code>	Should the distance be normalized? Only supported for <code>symmetric2</code> .

...	Currently ignored.
gcm	Optionally, a matrix to use for the global cost matrix calculations. It should have $NROW(y)+1$ columns, and $NROW(x)+1$ rows for <code>backtrack = TRUE</code> or 2 rows for <code>backtrack = FALSE</code> . Used internally for memory optimization. If provided, it will be modified <i>in place</i> by C code, except in the parallel version in <code>proxy::dist()</code> which ignores it for thread-safe reasons.
error.check	Logical indicating whether the function should try to detect inconsistencies and give more informative errors messages. Also used internally to avoid repeating checks.

Details

If `backtrack` is `TRUE`, the mapping of indices between series is returned in a list.

The windowing constraint uses a centered window. The calculations expect a value in `window.size` that represents the distance between the point considered and one of the edges of the window. Therefore, if, for example, `window.size = 10`, the warping for an observation x_i considers the points between x_{i-10} and x_{i+10} , resulting in $10(2) + 1 = 21$ observations falling within the window.

Value

The DTW distance. For `backtrack = TRUE`, a list with:

- `distance`: The DTW distance.
- `index1`: x indices for the matched elements in the warping path.
- `index2`: y indices for the matched elements in the warping path.

Proxy version

The version registered with `dist` is custom (`loop = FALSE` in `pr_DB`). The custom function handles parallelization directly (with `foreach`).

It also includes symmetric optimizations to calculate only half a distance matrix when appropriate. Only one list of series should be provided. If you want to avoid this optimization, call `dist` by giving the same list of series in both `x` and `y`.

In order for symmetry to apply here, the following must be true: no window constraint is used (`window.size` is `NULL`) or, if one is used, all series have the same length.

Note

The DTW algorithm (and the functions that depend on it) might return different values in 32 bit installations compared to 64 bit ones.

dtw_lb

*DTW distance matrix guided by Lemire's improved lower bound***Description**

Calculation of a distance matrix with the Dynamic Time Warping (DTW) distance guided by Lemire's improved lower bound (LB_Improved).

Usage

```
dtw_lb(x, y = NULL, window.size = NULL, norm = "L1", error.check = TRUE,
       pairwise = FALSE, dtw.func = "dtw_basic", nn.margin = 1L, ...)
```

Arguments

<code>x, y</code>	A matrix or data frame where rows are time series, or a list of time series.
<code>window.size</code>	Window size to use with the LB and DTW calculation. See details.
<code>norm</code>	Pointwise distance. Either "L1" for Manhattan distance or "L2" for Euclidean.
<code>error.check</code>	Logical indicating whether the function should try to detect inconsistencies and give more informative errors messages. Also used internally to avoid repeating checks.
<code>pairwise</code>	Calculate pairwise distances?
<code>dtw.func</code>	Which function to use for core DTW the calculations, either "dtw" or "dtw_basic". See dtw::dtw() and dtw_basic() .
<code>nn.margin</code>	Either 1 to search for nearest neighbors row-wise, or 2 to search column-wise. Only implemented for <code>dtw.func = "dtw_basic"</code> .
<code>...</code>	Further arguments for <code>dtw.func</code> or lb_improved() .

Details

This function first calculates an initial estimate of a distance matrix between two sets of time series using [lb_improved\(\)](#) (the [proxy::dist\(\)](#) version). Afterwards, it uses the estimate to calculate the corresponding true DTW distance between *only* the nearest neighbors of each series in `x` found in `y`, and it continues iteratively until no changes in the nearest neighbors occur.

If only `x` is provided, the distance matrix is calculated between all its time series, effectively returning a matrix filled with the LB_Improved values.

This could be useful in case one is interested in only the nearest neighbor of one or more series within a dataset.

The windowing constraint uses a centered window. The calculations expect a value in `window.size` that represents the distance between the point considered and one of the edges of the window. Therefore, if, for example, `window.size = 10`, the warping for an observation x_i considers the points between x_{i-10} and x_{i+10} , resulting in $10(2) + 1 = 21$ observations falling within the window.

Value

The distance matrix with class `crossdist`.

Parallel Computing

Please note that running tasks in parallel does **not** guarantee faster computations. The overhead introduced is sometimes too large, and it's better to run tasks sequentially.

The user can register a parallel backend, e.g. with the **doParallel** package, in order to attempt to speed up the calculations (see the examples).

Note

This function uses a lower bound that is only defined for time series of equal length.

A considerably large dataset is probably necessary before this is faster than using `dtw_basic()` with `proxy::dist()`. Also note that `lb_improved()` calculates warping envelopes for the series in `y`, so be careful with the provided order and `nn.margin` (see examples).

Author(s)

Alexis Sarda-Espinosa

References

Lemire D (2009). "Faster retrieval with a two-pass dynamic-time-warping lower bound." *Pattern Recognition*, 42(9), pp. 2169 - 2180. ISSN 0031-3203, <http://dx.doi.org/10.1016/j.patcog.2008.11.030>, <http://www.sciencedirect.com/science/article/pii/S0031320308004925>.

See Also

`lb_keogh()`, `lb_improved()`

Examples

```
# Load data
data(uciCT)

# Reinterpolate to same length
data <- reinterpolate(CharTraj, new.length = max(lengths(CharTraj)))

# Calculate the DTW distance between a certain subset aided with the lower bound
system.time(d <- dtw_lb(data[1:5], data[6:50], window.size = 20L))

# Nearest neighbors
NN1 <- apply(d, 1L, which.min)

# Calculate the DTW distances between all elements (slower)
system.time(d2 <- proxy::dist(data[1:5], data[6:50], method = "DTW",
                             window.type = "sakoechiba", window.size = 20L))
```

```

# Nearest neighbors
NN2 <- apply(d2, 1L, which.min)

# Calculate the DTW distances between all elements using dtw_basic
# (actually faster, see notes)
system.time(d3 <- proxy::dist(data[1:5], data[6:50], method = "DTW_BASIC",
                             window.size = 20L))

# Nearest neighbors
NN3 <- apply(d3, 1L, which.min)

# Change order and margin for nearest neighbor search
# (usually fastest, see notes)
system.time(d4 <- dtw_lb(data[6:50], data[1:5],
                        window.size = 20L, nn.margin = 2L))

# Nearest neighbors *column-wise*
NN4 <- apply(d4, 2L, which.min)

# Same results?
identical(NN1, NN2)
identical(NN1, NN3)
identical(NN1, NN4)

## Not run:
#### Running DTW_LB with parallel support
# For such a small dataset, this is probably slower in parallel
require(doParallel)

# Create parallel workers
cl <- makeCluster(detectCores())
invisible(clusterEvalQ(cl, library(dtwclust)))
registerDoParallel(cl)

# Distance matrix
D <- dtw_lb(data[1:50], data[51:100], window.size = 20)

# Stop parallel workers
stopCluster(cl)

# Return to sequential computations
registerDoSEQ()

# Nearest neighbors
NN <- apply(D, 1, which.min)
cbind(names(data[1:50]), names(data[51:100][NN]))

## End(Not run)

```

Description

Distance based on (triangular) global alignment kernels.

Usage

```
GAK(x, y, ..., sigma = NULL, window.size = NULL, normalize = TRUE,
    logs = NULL, error.check = TRUE)
```

Arguments

<code>x, y</code>	Time series. A multivariate series should have time spanning the rows and variables spanning the columns.
<code>...</code>	Currently ignored.
<code>sigma</code>	Parameter for the Gaussian kernel's width. See details for the interpretation of NULL.
<code>window.size</code>	Parameterization of the constraining band (T in Cuturi (2011)). See details.
<code>normalize</code>	Normalize the result by considering diagonal terms.
<code>logs</code>	Optionally, a matrix with $\max(\text{NROW}(x), \text{NROW}(y)) + 1$ rows and 3 columns to use for the logarithm calculations. Used internally for memory optimization. If provided, it will be modified <i>in place</i> by C code, except in the parallel version in <code>proxy::dist()</code> which ignores it for thread-safe reasons.
<code>error.check</code>	Logical indicating whether the function should try to detect inconsistencies and give more informative errors messages. Also used internally to avoid repeating checks.

Details

This function uses the Triangular Global Alignment Kernel (TGAK) described in Cuturi (2011). It supports series of different length and multivariate series, so long as the ratio of the series' lengths don't differ by more than 2 (or less than 0.5).

The `window.size` parameter is similar to the one used in DTW, so NULL signifies no constraint, and its value should be greater than 1 if used with series of different length.

The Gaussian kernel is parameterized by `sigma`. Providing NULL means that the value will be estimated by using the strategy mentioned in Cuturi (2011) with a constant of 1. This estimation is subject to **randomness**, so consider estimating the value once and re-using it (the estimate is returned as an attribute of the result). See the examples.

For more information, refer to the package vignette and the referenced article.

Value

The logarithm of the GAK if `normalize = FALSE`, otherwise 1 minus the normalized GAK. The value of `sigma` is assigned as an attribute of the result.

Proxy version

The version registered with `dist` is custom (loop = FALSE in `pr_DB`). The custom function handles parallelization directly (with `foreach`).

It also includes symmetric optimizations to calculate only half a distance matrix when appropriate. Only one list of series should be provided. If you want to avoid this optimization, call `dist` by giving the same list of series in both x and y.

Note

The estimation of sigma does *not* depend on `window.size`.

If `normalize` is set to FALSE, the returned value is **not** a distance, rather a similarity. The `proxy::dist()` version is thus always normalized. Use `proxy::simil()` with method set to "uGAK" if you want the unnormalized similarities.

A constrained unnormalized calculation (i.e. with `window.size > 0` and `normalize = FALSE`) will return negative infinity if `abs(NROW(x) - NROW(y)) > window.size`. Since the function won't perform calculations in that case, it might be faster, but if this behavior is not desired, consider reinterpolating the time series (see `reinterpolate()`) or increasing the window size.

References

Cuturi, M. (2011). Fast global alignment kernels. In *Proceedings of the 28th international conference on machine learning (ICML-11)* (pp. 929-936).

Examples

```
## Not run:
data(uciCT)

set.seed(832)
GAKd <- proxy::dist(zscore(CharTraj), method = "gak",
                    pairwise = TRUE, window.size = 18L)

# Obtained estimate of sigma
sigma <- attr(GAKd, "sigma")

# Use value for clustering
tsclust(CharTraj, k = 20L,
        distance = "gak", centroid = "shape",
        trace = TRUE,
        args = tsclust_args(dist = list(sigma = sigma,
                                         window.size = 18L)))

## End(Not run)

# Unnormalized similarities
proxy::simil(CharTraj[1L:5L], method = "ugak")
```

lb_improved	<i>Lemire's improved DTW lower bound</i>
-------------	------------------------------------------

Description

This function calculates an improved lower bound (LB) on the Dynamic Time Warp (DTW) distance between two time series. It uses a Sakoe-Chiba constraint.

Usage

```
lb_improved(x, y, window.size = NULL, norm = "L1", lower.env = NULL,
            upper.env = NULL, force.symmetry = FALSE, error.check = TRUE)
```

Arguments

<code>x</code>	A time series (reference).
<code>y</code>	A time series with the same length as <code>x</code> (query).
<code>window.size</code>	Window size for envelope calculation. See details.
<code>norm</code>	Vector norm. Either "L1" for Manhattan distance or "L2" for Euclidean.
<code>lower.env</code>	Optionally, a pre-computed lower envelope for <code>y</code> can be provided (non-proxy version only).
<code>upper.env</code>	Optionally, a pre-computed upper envelope for <code>y</code> can be provided (non-proxy version only).
<code>force.symmetry</code>	If TRUE, a second lower bound is calculated by swapping <code>x</code> and <code>y</code> , and whichever result has a <i>higher</i> distance value is returned. The proxy version can only work if a square matrix is obtained, but use carefully.
<code>error.check</code>	Logical indicating whether the function should try to detect inconsistencies and give more informative errors messages. Also used internally to avoid repeating checks.

Details

The reference time series should go in `x`, whereas the query time series should go in `y`.

If the envelopes are provided, they should be provided together. If either one is missing, both will be computed.

The windowing constraint uses a centered window. The calculations expect a value in `window.size` that represents the distance between the point considered and one of the edges of the window. Therefore, if, for example, `window.size = 10`, the warping for an observation x_i considers the points between x_{i-10} and x_{i+10} , resulting in $10(2) + 1 = 21$ observations falling within the window.

Value

The improved lower bound for the DTW distance.

Proxy version

The version registered with `dist` is custom (loop = FALSE in `pr_DB`). The custom function handles parallelization directly (with `foreach`).

Note

The lower bound is only defined for time series of equal length and is **not** symmetric.

If you wish to calculate the lower bound between several time series, it would be better to use the version registered with the proxy package, since it includes some small optimizations. The convention mentioned above for references and queries still holds. See the examples.

The proxy version of `force.symmetry` should only be used when only `x` is provided or both `x` and `y` are identical. It compares the lower and upper triangular of the resulting distance matrix and forces symmetry in such a way that the tightest lower bound is obtained.

References

Lemire D (2009). "Faster retrieval with a two-pass dynamic-time-warping lower bound ." *Pattern Recognition*, **42**(9), pp. 2169 - 2180. ISSN 0031-3203, <http://dx.doi.org/10.1016/j.patcog.2008.11.030>, <http://www.sciencedirect.com/science/article/pii/S0031320308004925>.

Examples

```
# Sample data
data(uciCT)

# Lower bound distance between two series
d.lbi <- lb_improved(CharTraj[[1]], CharTraj[[2]], window.size = 20)

# Corresponding true DTW distance
d.dtw <- dtw(CharTraj[[1]], CharTraj[[2]],
             window.type = "sakoechiba", window.size = 20)$distance

d.lbi <= d.dtw

# Calculating the LB between several time series using the 'proxy' package
# (notice how both arguments must be lists)
D.lbi <- proxy::dist(CharTraj[1], CharTraj[2:5], method = "LB_Improved",
                   window.size = 20, norm = "L2")

# Corresponding true DTW distance
D.dtw <- proxy::dist(CharTraj[1], CharTraj[2:5], method = "dtw_basic",
                   norm = "L2", window.size = 20)

D.lbi <= D.dtw
```

lb_keogh	<i>Keogh's DTW lower bound</i>
----------	--------------------------------

Description

This function calculates a lower bound (LB) on the Dynamic Time Warp (DTW) distance between two time series. It uses a Sakoe-Chiba constraint.

Usage

```
lb_keogh(x, y, window.size = NULL, norm = "L1", lower.env = NULL,
         upper.env = NULL, force.symmetry = FALSE, error.check = TRUE)
```

Arguments

x	A time series (reference).
y	A time series with the same length as x (query).
window.size	Window size for envelope calculation. See details.
norm	Vector norm. Either "L1" for Manhattan distance or "L2" for Euclidean.
lower.env	Optionally, a pre-computed lower envelope for y can be provided (non-proxy version only).
upper.env	Optionally, a pre-computed upper envelope for y can be provided (non-proxy version only).
force.symmetry	If TRUE, a second lower bound is calculated by swapping x and y, and whichever result has a <i>higher</i> distance value is returned. The proxy version can only work if a square matrix is obtained, but use carefully.
error.check	Logical indicating whether the function should try to detect inconsistencies and give more informative errors messages. Also used internally to avoid repeating checks.

Details

The reference time series should go in x, whereas the query time series should go in y.

If the envelopes are provided, they should be provided together. If either one is missing, both will be computed.

The windowing constraint uses a centered window. The calculations expect a value in `window.size` that represents the distance between the point considered and one of the edges of the window. Therefore, if, for example, `window.size = 10`, the warping for an observation x_i considers the points between x_{i-10} and x_{i+10} , resulting in $10(2) + 1 = 21$ observations falling within the window.

Value

A list with:

- `d`: The lower bound of the DTW distance.
- `upper.env`: The time series of `y`'s upper envelope.
- `lower.env`: The time series of `y`'s lower envelope.

Proxy version

The version registered with `dist` is custom (`loop = FALSE` in `pr_DB`). The custom function handles parallelization directly (with `foreach`).

Note

The lower bound is only defined for time series of equal length and is **not** symmetric.

If you wish to calculate the lower bound between several time series, it would be better to use the version registered with the `proxy` package, since it includes some small optimizations. The convention mentioned above for references and queries still holds. See the examples.

The proxy version of `force.symmetry` should only be used when only `x` is provided or both `x` and `y` are identical. It compares the lower and upper triangular of the resulting distance matrix and forces symmetry in such a way that the tightest lower bound is obtained.

References

Keogh E and Ratanamahatana CA (2005). "Exact indexing of dynamic time warping." *Knowledge and information systems*, **7**(3), pp. 358-386.

Examples

```
# Sample data
data(uciCT)

# Lower bound distance between two series
d.lbk <- lb_keogh(CharTraj[[1]], CharTraj[[2]], window.size = 20)$d

# Corresponding true DTW distance
d.dtw <- dtw(CharTraj[[1]], CharTraj[[2]],
             window.type = "sakoechiba", window.size = 20)$distance

d.lbk <= d.dtw

# Calculating the LB between several time series using the 'proxy' package
# (notice how both arguments must be lists)
D.lbk <- proxy::dist(CharTraj[1], CharTraj[2:5], method = "LB_Keogh",
                    window.size = 20, norm = "L2")

# Corresponding true DTW distance
D.dtw <- proxy::dist(CharTraj[1], CharTraj[2:5], method = "dtw_basic",
                    norm = "L2", window.size = 20)
```

```
D.lbk <= D.dtw
```

NCCc

*Cross-correlation with coefficient normalization***Description**

This function uses FFT to compute the cross-correlation sequence between two series. They need not be of equal length.

Usage

```
NCCc(x, y)
```

Arguments

`x, y` Univariate time series.

Value

The cross-correlation sequence with length $\text{length}(x) + \text{length}(y) - 1L$.

References

Paparrizos J and Gravano L (2015). “k-Shape: Efficient and Accurate Clustering of Time Series.” In *Proceedings of the 2015 ACM SIGMOD International Conference on Management of Data*, series SIGMOD '15, pp. 1855-1870. ISBN 978-1-4503-2758-9, <http://doi.org/10.1145/2723372.2737793>.

See Also

[SBD\(\)](#)

pdc_configs

*Helper function for preprocessing/distance/centroid configurations***Description**

Create preprocessing, distance and centroid configurations for [compare_clusterings_configs\(\)](#). All functions use [base::expand.grid\(\)](#).

Usage

```
pdc_configs(type = c("preproc", "distance", "centroid"), ...,
  partitional = NULL, hierarchical = NULL, fuzzy = NULL, tadpole = NULL,
  share.config = c("p", "h", "f", "t"))
```

Arguments

type	Which type of function is being targeted by this configuration.
...	Any number of named nested lists with functions and arguments that will be shared by all clusterings. See details.
partitional	A named list of lists with functions and arguments for partitional clusterings.
hierarchical	A named list of lists with functions and arguments for hierarchical clusterings.
fuzzy	A named list of lists with functions and arguments for fuzzy clusterings.
tadpole	A named list of lists with functions and arguments for TADPole clusterings.
share.config	A character vector specifying which clusterings should include the shared lists (the ones specified in ...). It must be any combination of (possibly abbreviated): partitional, hierarchical, fuzzy, tadpole.

Details

The named lists are interpreted in the following way: the name of each element of the list will be considered to be a function name, and the elements of the nested list will be the possible parameters for the function. Each function must have at least an empty list. The parameters may be vectors that specify different values to be tested.

For preprocessing, the special name `none` signifies no preprocessing.

For centroids, the special name `default` leaves the centroid unspecified.

Please see the examples in [compare_clusterings\(\)](#) to see how this is used.

Value

A list for each clustering, each of which includes a data frame with the computed configurations.

randIndex

Compare partitions

Description

No longer supported directly in **dtwclust**. Please refer to [cvi\(\)](#)

Usage

```
## S4 method for signature 'dtwclust,ANY'
randIndex(x, y, correct = TRUE,
  original = !correct)

## S4 method for signature 'ANY,dtwclust'
randIndex(x, y, correct = TRUE,
  original = !correct)

## S4 method for signature 'dtwclust,dtwclust'
randIndex(x, y, correct = TRUE,
  original = !correct)
```

Arguments

x, y, correct, original
 See [flexclust::randIndex\(\)](#).

reinterpolate	<i>Wrapper for simple linear reinterpolation</i>
---------------	--------------------------------------------------

Description

This function is just a wrapper for the native function [stats::approx\(\)](#) to do simple linear reinterpolation. It also supports matrices, data frames, and lists of time series.

Usage

```
reinterpolate(x, new.length, multivariate = FALSE)
```

Arguments

x	Data to reinterpolate. Either a vector, a matrix/data.frame where each row is to be reinterpolated, or a list of vectors/matrices.
new.length	Desired length of the output series.
multivariate	Is x a multivariate time series? It will be detected automatically if a list is provided in x.

Details

Multivariate series must have time spanning the rows and variables spanning the columns.

Value

Reinterpolated time series

Examples

```
data(uciCT)

# list of univariate series
series <- reinterpolate(CharTraj, 205L)

# list of multivariate series
series <- reinterpolate(CharTrajMV, 205L)

# single multivariate series
series <- reinterpolate(CharTrajMV[[1L]], 205L, TRUE)
```

SBD

*Shape-based distance***Description**

Distance based on coefficient-normalized cross-correlation as proposed by Paparrizos and Gravano (2015) for the k-Shape clustering algorithm.

Usage

```
SBD(x, y, znorm = FALSE, error.check = TRUE)
```

Arguments

<code>x, y</code>	Univariate time series.
<code>znorm</code>	Logical. Should each series be z-normalized before calculating the distance?
<code>error.check</code>	Logical indicating whether the function should try to detect inconsistencies and give more informative errors messages. Also used internally to avoid repeating checks.

Details

This distance works best if the series are *z-normalized*. If not, at least they should have appropriate amplitudes, since the values of the signals **do** affect the outcome.

If `x` and `y` **do not** have the same length, it would be best if the longer sequence is provided in `y`, because it will be shifted to match `x`. After matching, the series may have to be truncated or extended and padded with zeros if needed.

The output values lie between 0 and 2, with 0 indicating perfect similarity.

Value

A list with:

- `dist`: The shape-based distance between `x` and `y`.
- `yshift`: A shifted version of `y` so that it optimally matches `x` (based on `NCCc()`).

Proxy version

The version registered with `dist` is custom (`loop = FALSE` in `pr_DB`). The custom function handles parallelization directly (with `foreach`).

It also includes symmetric optimizations to calculate only half a distance matrix when appropriate. Only one list of series should be provided. If you want to avoid this optimization, call `dist` by giving the same list of series in both `x` and `y`.

In some situations, e.g. for relatively small distance matrices, the overhead introduced by the logic that computes only half the distance matrix can be bigger than just calculating the whole matrix.

Note

If you wish to calculate the distance between several time series, it would be better to use the version registered with the proxy package, since it includes some small optimizations. See the examples.

This distance is calculated with help of the Fast Fourier Transform, so it can be sensitive to numerical precision. Thus, this function (and the functions that depend on it) might return different values in 32 bit installations compared to 64 bit ones.

References

Paparrizos J and Gravano L (2015). “k-Shape: Efficient and Accurate Clustering of Time Series.” In *Proceedings of the 2015 ACM SIGMOD International Conference on Management of Data*, series SIGMOD '15, pp. 1855-1870. ISBN 978-1-4503-2758-9, <http://doi.org/10.1145/2723372.2737793>.

See Also

`NCCc()`, `shape_extraction()`

Examples

```
# load data
data(uciCT)

# distance between series of different lengths
sbd <- SBD(CharTraj[[1]], CharTraj[[100]], znorm = TRUE)$dist

# cross-distance matrix for series subset (notice the two-list input)
sbd <- proxy::dist(CharTraj[1:10], CharTraj[1:10], method = "SBD", znorm = TRUE)
```

shape_extraction

Shape average of several time series

Description

Time-series shape extraction based on optimal alignments as proposed by Paparrizos and Gravano (2015), for the k-Shape clustering algorithm.

Usage

```
shape_extraction(X, centroid = NULL, znorm = FALSE, ...,
  error.check = TRUE)
```

Arguments

<code>X</code>	A matrix or data frame where each row is a time series, or a list where each element is a time series. Multivariate series should be provided as a list of matrices where time spans the rows and the variables span the columns.
<code>centroid</code>	Optionally, a time series to use as reference. Defaults to a random series of <code>X</code> if <code>NULL</code> . For multivariate series, this should be a matrix with the same characteristics as the matrices in <code>X</code> . It will be z-normalized.
<code>znorm</code>	Logical flag. Should z-scores be calculated for <code>X</code> before processing?
<code>...</code>	Further arguments for <code>zscore()</code> .
<code>error.check</code>	Logical indicating whether the function should try to detect inconsistencies and give more informative errors messages. Also used internally to avoid repeating checks.

Details

This works only if the series are *z-normalized*, since the output will also have this normalization.

The resulting centroid will have the same length as `centroid` if provided. Otherwise, there are two possibilities: if all series from `X` have the same length, all of them will be used as-is, and the output will have the same length as the series; if series have different lengths, a series will be chosen at random and used as reference. The output series will then have the same length as the chosen series.

This centroid computation is casted as an optimization problem called maximization of Rayleigh Quotient. It depends on the `SBD()` algorithm. See the cited article for more details.

Value

Centroid time series (z-normalized).

References

Paparrizos J and Gravano L (2015). “k-Shape: Efficient and Accurate Clustering of Time Series.” In *Proceedings of the 2015 ACM SIGMOD International Conference on Management of Data*, series SIGMOD '15, pp. 1855-1870. ISBN 978-1-4503-2758-9, <http://doi.org/10.1145/2723372.2737793>.

See Also

`SBD()`, `zscore()`

Examples

```
# Sample data
data(uciCT)

# Normalize desired subset
X <- zscore(CharTraj[1:5])

# Obtain centroid series
```

```

C <- shape_extraction(X)

# Result
matplot(do.call(cbind, X),
        type = "l", col = 1:5)
points(C)

```

SparseDistmat-class *Sparse distance matrix*

Description

Reference class that is used internally for PAM centroids when `pam.precompute = FALSE`. It allows for mutable state. It contains [Distmat](#).

Fields

`distmat` The sparse matrix.

`symmetric` Logical indicating if the matrix is symmetric.

`distmat_indices` External pointer (C++ class) with the indices of existing values within the matrix, and the method to update them.

Methods

`initialize(..., distmat, series, distance, control, error.check = TRUE)` Initialization based on needed parameters

SparseDistmat-generics *Generics for SparseDistmat*

Description

Generics with methods for [SparseDistmat](#).

Usage

```

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

## S4 method for signature 'SparseDistmat,ANY,ANY,ANY'
x[i, j, ..., drop = TRUE]

```

Arguments

object	A SparseDistmat object.
x	A SparseDistmat object.
i	Row indices.
j	Column indices.
...	Ignored.
drop	Logical to drop dimensions after subsetting.

Details

Accessing matrix elements with `[]` first calculates the values if necessary.

TADPole

TADPole clustering

Description

Time-series Anytime Density Peaks Clustering as proposed by Begum et al. (2015).

Usage

```
TADPole(data, k = 2L, dc, window.size, error.check = TRUE, lb = "lbk",
        trace = FALSE)
```

Arguments

data	A matrix or data frame where each row is a time series, or a list where each element is a time series. Multivariate series are not supported.
k	The number of desired clusters. Can be a vector with several values.
dc	The cutoff distance(s). May be a vector with several values.
window.size	Window size constraint for DTW (Sakoe-Chiba). See details.
error.check	Logical indicating whether the function should try to detect inconsistencies and give more informative errors messages. Also used internally to avoid repeating checks.
lb	Which lower bound to use, "lbk" for lb_keogh() or "lbi" for lb_improved() .
trace	Logical flag. If TRUE, more output regarding the progress is printed to screen.

Details

This function can be called either directly or through `dtwclust()` and `tsclust()`.

TADPole clustering adopts a relatively new clustering framework and adapts it to time series clustering with DTW. See the cited article for the details of the algorithm.

Because of the way the algorithm works, it can be considered a kind of Partitioning Around Medoids (PAM). This means that the cluster centroids are always elements of the data. However, this algorithm is deterministic, depending on the value of `dc`.

The algorithm first uses the DTW's upper and lower bounds (Euclidean and LB_Keogh respectively) to find series with many close neighbors (in DTW space). Anything below the cutoff distance (`dc`) is considered a neighbor. Aided with this information, the algorithm then tries to prune as many DTW calculations as possible in order to accelerate the clustering procedure. The series that lie in dense areas (i.e. that have lots of neighbors) are taken as cluster centroids.

The algorithm relies on the DTW bounds, which are only defined for univariate time series of equal length.

Parallelization is supported, but given the internal optimizations, it may only be useful if multiple `dc` values are specified in the same call.

The windowing constraint uses a centered window. The calculations expect a value in `window.size` that represents the distance between the point considered and one of the edges of the window. Therefore, if, for example, `window.size = 10`, the warping for an observation x_i considers the points between x_{i-10} and x_{i+10} , resulting in $10(2) + 1 = 21$ observations falling within the window.

Value

A list with:

- `cl`: Cluster indices.
- `centroids`: Indices of the centroids.
- `distCalcPercentage`: Percentage of distance calculations that were actually performed.

For multiple `k/dc` values, a list of lists is returned, each internal list having the aforementioned elements.

References

Begum N, Ulanova L, Wang J and Keogh E (2015). "Accelerating Dynamic Time Warping Clustering with a Novel Admissible Pruning Strategy." In *Conference on Knowledge Discovery and Data Mining*, series KDD '15. ISBN 978-1-4503-3664-2/15/08, <http://dx.doi.org/10.1145/2783258.2783286>.

tsclust

Time series clustering

Description

This is the main function to perform time series clustering. See the details and the examples for more information, as well as the included package vignette (which can be loaded by typing `vignette("dtwclust")`). A convenience wrapper is available in [compare_clusterings\(\)](#).

Usage

```
tsclust(series = NULL, type = "partitional", k = 2L, ...,
        preproc = NULL, distance = "dtw_basic", centroid = ifelse(type ==
        "fuzzy", "fcm", "pam"), control = do.call(paste0(type, "_control"), list()),
        args = tsclust_args(), seed = NULL, trace = FALSE, error.check = TRUE)
```

Arguments

series	A list of series, a numeric matrix or a data frame. Matrices and data frames are coerced to a list row-wise (see tslist()).
type	What type of clustering method to use: "partitional", "hierarchical", "tadpole" or "fuzzy".
k	Number of desired clusters. It may be a numeric vector with different values.
...	Arguments to pass to preprocessing, centroid and distance functions (added to args). Also passed to method from hierarchical_control() if it happens to be a function, and to stats::hclust() if it contains the members parameter.
preproc	Function to preprocess data. Defaults to zscore() <i>only</i> if centroid = "shape", but will be replaced by a custom function if provided.
distance	A registered distance from proxy::dist() . Ignored for type = "tadpole".
centroid	Either a supported string or an appropriate function to calculate centroids when using partitional or prototypes for hierarchical/tadpole methods.
control	An appropriate list of controls. See tsclust-controls
args	An appropriate list of arguments for preprocessing, distance and centroid functions. See tsclust_args()
seed	Random seed for reproducibility.
trace	Logical flag. If TRUE, more output regarding the progress is printed to screen.
error.check	Logical indicating whether the function should try to detect inconsistencies and give more informative errors messages. Also used internally to avoid repeating checks.

Details

Partitional and fuzzy clustering procedures use a custom implementation. Hierarchical clustering is done with `stats::hclust()` by default. TADPole clustering uses the `TADPole()` function. Specifying `type = "partitional"`, `preproc = zscore`, `distance = "sbd"` and `centroid = "shape"` is equivalent to the k-Shape algorithm (Paparrizos and Gravano 2015).

The series may be provided as a matrix, a data frame or a list. Matrices and data frames are coerced to a list, both row-wise. Only lists can have series with different lengths or multiple dimensions. Most of the optimizations require series to have the same length, so consider reinterpolating them to save some time (see Ratanamahatana and Keogh 2004; `reinterpolate()`). No missing values are allowed.

In the case of multivariate time series, they should be provided as a list of matrices, where time spans the rows of each matrix and the variables span the columns (see `CharTrajMV` for an example). At the moment, only DTW, DTW2 and GAK support such series. You can of course create your own custom distances. All included centroid functions should work with the aforementioned format, although shape is *not* recommended. Note that the `plot` method will simply append all dimensions (columns) one after the other.

Value

An object with an appropriate class from `TSClusters`.

If `control@nrep > 1` and a partitional procedure is used, `length(method) > 1` and hierarchical procedures are used, or `length(k) > 1`, a list of objects is returned.

Centroid Calculation

In the case of partitional/fuzzy algorithms, a suitable function should calculate the cluster centroids at every iteration. In this case, the centroids are themselves time series. Fuzzy clustering uses the standard fuzzy c-means centroid by default.

In either case, a custom function can be provided. If one is provided, it will receive the following parameters with the shown names (examples for partitional clustering are shown in parentheses):

- `x`: The *whole* data list (`list(ts1, ts2, ts3)`)
- `cl_id`: An integer vector with length equal to the number of series in data, indicating which cluster a series belongs to (`c(1L, 2L, 2L)`)
- `k`: The desired number of total clusters (`2L`)
- `cent`: The current centroids in order, in a list (`list(centroid1, centroid2)`)
- `cl_old`: The membership vector of the *previous* iteration (`c(1L, 1L, 2L)`)
- The elements of `...` that match its formal arguments

In case of fuzzy clustering, the membership vectors (2nd and 5th elements above) are matrices with number of rows equal to amount of elements in the data, and number of columns equal to the number of desired clusters. Each row must sum to 1.

The other option is to provide a character string for the custom implementations. The following options are available:

- `"mean"`: The average along each dimension. In other words, the average of all x_i^j among the j series that belong to the same cluster for all time points t_i .

- "median": The median along each dimension. Similar to mean.
- "shape": Shape averaging. By default, all series are z-normalized in this case, since the resulting centroids will also have this normalization. See [shape_extraction\(\)](#) for more details.
- "dba": DTW Barycenter Averaging. See [DBA\(\)](#) for more details.
- "pam": Partition around medoids (PAM). This basically means that the cluster centroids are always one of the time series in the data. In this case, the distance matrix can be pre-computed once using all time series in the data and then re-used at each iteration. It usually saves overhead overall for small datasets (see [tsclust-controls](#)).
- "fcm": Fuzzy c-means. Only supported for fuzzy clustering and used by default in that case.
- "fcmdd": Fuzzy c-medoids. Only supported for fuzzy clustering. It **always** precomputes the whole cross-distance matrix.

These check for the special cases where parallelization might be desired. Note that only shape, dba, pam and fcmdd support series of different length. Also note that, for shape and dba, this support has a caveat: the final centroids' length will depend on the length of those series that were randomly chosen at the beginning of the clustering algorithm. For example, if the series in the dataset have a length of either 10 or 15, 2 clusters are desired, and the initial choice selects two series with length of 10, the final centroids will have this same length.

As special cases, if hierarchical or tadpole clustering is used, you can provide a centroid function that takes a list of series as input and returns a single centroid series. These centroids are returned in the centroids slot. By default, a type of PAM centroid function is used.

Distance Measures

The distance measure to be used with partitional, hierarchical and fuzzy clustering can be modified with the distance parameter. The supported option is to provide a string, which must represent a compatible distance registered with proxy's [proxy::dist\(\)](#). Registration is done via [proxy::pr_DB\(\)](#), and extra parameters can be provided in `args$dist` (see the examples).

Note that you are free to create your own distance functions and register them. Optionally, you can use one of the following custom implementations (all registered with proxy):

- "dtw": DTW, optionally with a Sakoe-Chiba/Slanted-band constraint.
- "dtw2": DTW with L2 norm and optionally a Sakoe-Chiba/Slanted-band constraint. Read details below.
- "dtw_basic": A custom version of DTW with less functionality, but faster. See [dtw_basic\(\)](#).
- "dtw_lb": DTW with L1 or L2 norm and optionally a Sakoe-Chiba constraint. Some computations are avoided by first estimating the distance matrix with Lemire's lower bound and then iteratively refining with DTW. See [dtw_lb\(\)](#). Not suitable for `pam.precompute = TRUE` nor hierarchical clustering.
- "lbk": Keogh's lower bound with either L1 or L2 norm for the Sakoe-Chiba constraint. See [lb_keogh\(\)](#).
- "lbi": Lemire's lower bound with either L1 or L2 norm for the Sakoe-Chiba constraint. See [lb_improved\(\)](#).
- "sbd": Shape-based distance. See [SBD\(\)](#).
- "gak": Global alignment kernels. See [GAK\(\)](#).

DTW2 is done with `dtw::dtw()`, but it differs from the result you would obtain if you specify L2 as `dist.method`: with DTW2, pointwise distances (the local cost matrix) are calculated with L1 norm, *each* element of the matrix is squared and the result is fed into `dtw::dtw()`, which finds the optimum warping path. The square root of the resulting distance is *then* computed. See `dtw2()`.

Out of the aforementioned, only the distances based on DTW lower bounds *don't* support series of different length. The lower bounds are probably unsuitable for direct clustering unless series are very easily distinguishable.

If you know that the distance function is symmetric, and you use a hierarchical algorithm, or a partitional algorithm with PAM centroids, or fuzzy c-medoids, some time can be saved by calculating only half the distance matrix. Therefore, consider setting the symmetric control parameter to TRUE if this is the case.

Preprocessing

It is strongly advised to use z-normalization in case of `centroid = "shape"`, because the resulting series have this normalization (see `shape_extraction()`). Therefore, `zscore()` is the default in this case. The user can, however, specify a custom function that performs any transformation on the data, but the user must make sure that the format stays consistent, i.e. a list of time series.

Setting to NULL means no preprocessing (except for `centroid = "shape"`). A provided function will receive the data as first argument, followed by the contents of `args$preproc` that match its formal arguments.

It is convenient to provide this function if you're planning on using the `stats::predict()` generic (see also `tsclusters-methods`).

Repetitions

Due to their stochastic nature, partitional clustering is usually repeated several times with different random seeds to allow for different starting points. This function uses `rngtools::RNGseq()` to obtain different seed streams for each repetition, utilizing the seed parameter (if provided) to initialize it. If more than one repetition is made, the streams are returned in an attribute called `rng`.

Multiple values of `k` can also be provided to get different partitions using any type of clustering.

Repetitions are greatly optimized when PAM centroids are used and the whole distance matrix is precomputed, since said matrix is reused for every repetition, and can be computed in parallel (see Parallel section).

Parallel Computing

Please note that running tasks in parallel does **not** guarantee faster computations. The overhead introduced is sometimes too large, and it's better to run tasks sequentially.

The user can register a parallel backend, e.g. with the `doParallel` package, in order to attempt to speed up the calculations (see the examples).

If you register a parallel backend, the function will also try to do the calculation of the distance matrices in parallel. See the caveats in `tsclustFamily`. If the function requires special packages to be loaded, provide their names in the `packages` element of `control`. Note that "dtwclust" is always loaded in each parallel worker, so that doesn't need to be included. Alternatively, you may want to pre-load `dtwclust` in each worker with `parallel::clusterEvalQ()`.

In case of multiple repetitions, each worker gets a repetition task. Otherwise, the tasks (which can be a distance matrix or a centroid calculation) are usually divided into chunks according to the number of workers available.

Note

The lower bounds are defined only for time series of equal length.

The lower bounds are **not** symmetric, and DTW is not symmetric in general.

Author(s)

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References

Please refer to the package vignette references (which can be loaded by typing `vignette("dtwclust")`).

See Also

[TSClusters](#), [tsclusters-methods](#), [tsclustFamily](#), [tsclust-controls](#), [compare_clusterings\(\)](#).

Examples

```
#' NOTE: More examples are available in the vignette. Here are just some miscellaneous
#' examples that might come in handy. They should all work, but some don't run
#' automatically.

# Load data
data(uciCT)

# =====
# Simple partitional clustering with Euclidean distance and PAM centroids
# =====

# Reinterpolate to same length
series <- reinterpolate(CharTraj, new.length = max(lengths(CharTraj)))

# Subset for speed
series <- series[1:20]
labels <- CharTrajLabels[1:20]

# Making many repetitions
pc.l2 <- tsclust(series, k = 4L,
                 distance = "L2", centroid = "pam",
                 seed = 3247, trace = TRUE,
                 control = partitional_control(nrep = 10L))

# Cluster validity indices
sapply(pc.l2, cvi, b = labels)

# =====
# Hierarchical clustering with Euclidean distance
```

```
# =====

# Re-use the distance matrix from the previous example (all matrices are the same)
# Use all available linkage methods for function hclust
hc.l2 <- tsclust(series, type = "hierarchical",
                k = 4L, trace = TRUE,
                control = hierarchical_control(method = "all",
                                              distmat = pc.l2[[1L]]@distmat))

# Plot the best dendrogram according to variation of information
plot(hc.l2[[which.min(sapply(hc.l2, cvi, b = labels, type = "VI"))]])

# =====
# Multivariate time series
# =====

# Multivariate series, provided as a list of matrices
mv <- CharTrajMV[1L:20L]

# Using GAK distance
mvc <- tsclust(mv, k = 4L, distance = "gak", seed = 390,
              args = tsclust_args(dist = list(sigma = 100)))

# Note how the variables of each series are appended one after the other in the plot
plot(mvc)

## Not run:
# =====
# This function is more verbose but allows for more explicit fine-grained control
# =====

tsc <- tsclust(series, k = 4L,
              distance = "gak", centroid = "dba",
              preproc = zscore, seed = 382L, trace = TRUE,
              control = partitional_control(iter.max = 30L),
              args = tsclust_args(preproc = list(center = FALSE),
                                dist = list(window.size = 20L,
                                           sigma = 100),
                                cent = list(window.size = 15L,
                                           norm = "L2",
                                           trace = TRUE)))

# =====
# Registering a custom distance with the 'proxy' package and using it
# =====

# Normalized asymmetric DTW distance
ndtw <- function(x, y, ...) {
  dtw::dtw(x, y, step.pattern = asymmetric,
           distance.only = TRUE, ...)$normalizedDistance
}

# Registering the function with 'proxy'
```

```

if (!pr_DB$entry_exists("nDTW"))
  proxy::pr_DB$set_entry(FUN = ndtw, names=c("nDTW"),
                        loop = TRUE, type = "metric", distance = TRUE,
                        description = "Normalized asymmetric DTW")

# Subset of (original) data for speed
pc.ndtw <- tsclust(series[-1L], k = 4L,
                  distance = "nDTW",
                  seed = 8319,
                  trace = TRUE,
                  args = tsclust_args(dist = list(window.size = 18L)))

# Which cluster would the first series belong to?
# Notice that newdata is provided as a list
predict(pc.ndtw, newdata = series[1L])

# =====
# Custom hierarchical clustering
# =====

require(cluster)

hc.diana <- tsclust(series, type = "h", k = 4L,
                  distance = "L2", trace = TRUE,
                  control = hierarchical_control(method = diana))

plot(hc.diana, type = "sc")

# =====
# TADPole clustering
# =====

pc.tadp <- tsclust(series, type = "tadpole", k = 4L,
                  control = tadpole_control(dc = 1.5,
                                          window.size = 18L))

# Modify plot, show only clusters 3 and 4
plot(pc.tadp, clus = 3:4,
     labs.arg = list(title = "TADPole, clusters 3 and 4",
                     x = "time", y = "series"))

# Saving and modifying the ggplot object with custom time labels
require(scales)
t <- seq(Sys.Date(), len = length(series[[1L]]), by = "day")
gpc <- plot(pc.tadp, time = t, plot = FALSE)

gpc + scale_x_date(labels = date_format("%b-%Y"),
                  breaks = date_breaks("2 months"))

# =====
# Specifying a centroid function for prototype extraction in hierarchical clustering
# =====

```

```

# Seed is due to possible randomness in shape_extraction when selecting a basis series
hc.sbd <- tsclust(CharTraj, type = "hierarchical",
                  k = 20L, distance = "sbd",
                  preproc = zscore, centroid = shape_extraction,
                  seed = 320L)

plot(hc.sbd, type = "sc")

# =====
# Using parallel computation to optimize several random repetitions
# and distance matrix calculation
# =====
require(doParallel)

# Create parallel workers
cl <- makeCluster(detectCores())
invisible(clusterEvalQ(cl, library(dtwclust)))
registerDoParallel(cl)

## Use constrained DTW and PAM (less than a second with 8 cores)
pc.dtw <- tsclust(CharTraj, k = 20L, seed = 3251, trace = TRUE,
                  args = tsclust_args(dist = list(window.size = 18L)))

## Use constrained DTW with DBA centroids (~3 seconds with 8 cores)
pc.dba <- tsclust(CharTraj, k = 20L, centroid = "dba",
                  seed = 3251, trace = TRUE,
                  args = tsclust_args(dist = list(window.size = 18L),
                                       cent = list(window.size = 18L)))

#' Using distance based on global alignment kernels
#' (~35 seconds with 8 cores for all repetitions)
pc.gak <- tsclust(CharTraj, k = 20L,
                  distance = "gak",
                  centroid = "dba",
                  seed = 8319,
                  trace = TRUE,
                  control = partitional_control(nrep = 8L),
                  args = tsclust_args(dist = list(window.size = 18L),
                                       cent = list(window.size = 18L)))

# Stop parallel workers
stopCluster(cl)

# Return to sequential computations. This MUST be done if stopCluster() was called
registerDoSEQ()

## End(Not run)

```

Description

Control parameters for fine-grained control.

Usage

```
partitional_control(pam.precompute = TRUE, iter.max = 100L, nrep = 1L,
  symmetric = FALSE, packages = character(0L), distmat = NULL,
  pam.sparse = !pam.precompute)
```

```
hierarchical_control(method = "average", symmetric = FALSE,
  packages = character(0L), distmat = NULL)
```

```
fuzzy_control(fuzziness = 2, iter.max = 100L, delta = 0.001,
  packages = character(0L), symmetric = FALSE)
```

```
tadpole_control(dc, window.size, lb = "lbk")
```

```
tsclust_args(preproc = list(), dist = list(), cent = list())
```

Arguments

pam.precompute	Logical flag. Precompute the whole distance matrix once and reuse it on each iteration if using PAM centroids. Otherwise calculate distances at every iteration. See details.
iter.max	Integer. Maximum number of allowed iterations for partitional/fuzzy clustering.
nrep	Integer. How many times to repeat clustering with different starting points.
symmetric	Logical flag. Is the distance function symmetric? In other words, is <code>dist(x,y) == dist(y,x)</code> ? If TRUE, only half the distance matrix needs to be computed. Automatically detected and overridden for the distances included in dtwclust .
packages	Character vector with the names of any packages required for custom proxy functions. Since the distance entries are re-registered in each parallel worker if needed, this is probably useless, but just in case.
distmat	If available, the cross-distance matrix can be provided here. Only relevant for partitional with PAM centroids or hierarchical procedures.
pam.sparse	Attempt to use a sparse matrix for PAM centroids. See details.
method	Character vector with one or more linkage methods to use in hierarchical procedures (see stats::hclust()), the character "all" to use all of the available ones, or a function that performs hierarchical clustering based on distance matrices (e.g. cluster::diana()). See details.
fuzziness	Numeric. Exponent used for fuzzy clustering. Commonly termed <i>m</i> in the literature.
delta	Numeric. Convergence criterion for fuzzy clustering.
dc	The cutoff distance for the TADPole algorithm.
window.size	The window.size specifically for the TADPole algorithm.
lb	The lower bound to use with TADPole. Either "lbk" or "lbi".

preproc	A list of arguments for a preprocessing function to be used in <code>tsclust()</code> .
dist	A list of arguments for a distance function to be used in <code>tsclust()</code> .
cent	A list of arguments for a centroid function to be used in <code>tsclust()</code> .

Details

The functions essentially return their function arguments in a classed list, although some checks are performed.

Partitional

As of version 4.0.0, using `pam.precompute = FALSE` is optimized by defining a sparse matrix (see `Matrix::sparseMatrix()`) and updating it every iteration (except for "dtw_lb" distance). For smaller datasets, precomputing the whole distance matrix is still probably faster.

Explicitly setting both `pam.precompute` and `pam.sparse` to `FALSE` will reproduce previous behavior, and might be faster if the distance matrix is very big but the distance function is very quick.

Parallel computations for PAM centroids have the following considerations:

- If `pam.precompute` is `TRUE`, both distance matrix calculations and repetitions are done in parallel, regardless of `pam.sparse`.
- If `pam.precompute` is `FALSE` and `pam.sparse` is `TRUE`, repetitions are done sequentially, so that the distance calculations can be done in parallel and the sparse matrix updated iteratively.
- If both `pam.precompute` and `pam.sparse` are `FALSE`, repetitions are done in parallel, and each repetition performs distance calculations sequentially, but the sparse matrix cannot be updated iteratively.

Hierarchical

There are some limitations when using a custom hierarchical function in method: it will receive the lower triangular of the distance matrix as first argument (see `stats::as.dist()`) and the result should support the `stats::as.hclust()` generic. This functionality was added with the **cluster** package in mind, since its functions follow this convention, but other functions could be used if they are adapted to work similarly.

TADPole

When using TADPole, the `dist` argument list includes the `window.size` and specifies `norm = "L2"`.

TSClusters-class	<i>Class definition for TSClusters and derived classes</i>
------------------	------------------------------------------------------------

Description

Formal S4 classes for time-series clusters. See class hierarchy and slot organization at the bottom.

Details

The base class is TSClusters. The 3 classes that inherit from it are: PartitionalTSClusters, HierarchicalTSClusters and FuzzyTSClusters.

HierarchicalTSClusters also contain `stats::hclust()` as parent class.

Package **clue** is supported, but generics from **flexclust** are not. See also [tsclusters-methods](#).

If you want to transform a `dtwclust` object to TSClusters, just use:

```
as(dtwclust_obj, "TSClusters")
```

although it may not work perfectly.

Slots

`call` The function call.

`family` An object of class `tsclustFamily`.

`control` An appropriate control object for `tsclust()`. See [tsclust-controls](#).

`datalist` The provided data in the form of a list, where each element is a time series.

`type` A string indicating one of the supported clustering types of `tsclust()`.

`distance` A string indicating the distance used.

`centroid` A string indicating the centroid used.

`preproc` A string indicating the preprocessing used.

`k` Integer indicating the number of desired clusters.

`cluster` Integer vector indicating which cluster a series belongs to (crisp partition). For fuzzy clustering, this is based on **distance**, not on `fcluster`. For hierarchical, this is obtained by calling `stats::cutree()` with the given value of `k`.

`centroids` A list with the centroid time series.

`distmat` If computed, the cross-distance matrix.

`proctime` Time during function execution, as measured with `base::proc.time()`.

`dots` The contents of the original call's ellipsis (...).

`args` The contents of the original call's `args` parameter. See [tsclust_args\(\)](#).

`seed` The random seed that was used.

`iter` The number of iterations used.

`converged` A logical indicating whether the function converged.

`clusinfo` A data frame with two columns: `size` indicates the number of series each cluster has, and `av_dist` indicates, for each cluster, the average distance between series and their respective centroids (crisp partition).

`cldist` A column vector with the distance between each series in the data and its corresponding centroid (crisp partition).

`method` A string indicating which hierarchical method was used.

`fcluster` Numeric matrix that contains membership of fuzzy clusters. It has one row for each series and one column for each cluster. The rows must sum to 1. Only relevant for fuzzy clustering.

TSClusters

The base class contains the following slots:

- call
- family
- control
- datalist
- type
- distance
- centroid
- preproc
- k
- cluster
- centroids
- distmat
- proctime
- dots
- args
- seed

PartitionalTSClusters

This class adds the following slots to the base class:

- iter
- converged
- clusinfo
- cldist

HierarchicalTSClusters

This class adds the following slots to the base class:

- method
- clusinfo
- cldist

FuzzyTSClusters

This class adds the following slots to the base class:

- iter
- converged
- fcluster

See Also

[tsclusters-methods](#)

tsclusters-methods	<i>Methods for TSClusters</i>
--------------------	-------------------------------

Description

Methods associated with [TSClusters](#) and derived objects.

Usage

```
## S4 method for signature 'TSClusters'
initialize(.Object, ..., override.family = TRUE)

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

## S3 method for class 'TSClusters'
update(object, ..., evaluate = TRUE)

## S4 method for signature 'TSClusters'
update(object, ..., evaluate = TRUE)

## S3 method for class 'TSClusters'
predict(object, newdata = NULL, ...)

## S4 method for signature 'TSClusters'
predict(object, newdata = NULL, ...)

## S3 method for class 'TSClusters'
plot(x, y, ..., clus = seq_len(x@k), labs.arg = NULL,
      series = NULL, time = NULL, plot = TRUE, type = NULL)

## S4 method for signature 'TSClusters,missing'
plot(x, y, ..., clus = seq_len(x@k),
      labs.arg = NULL, series = NULL, time = NULL, plot = TRUE,
      type = NULL)
```

Arguments

.Object	A TSClusters prototype. You shouldn't use this, see Initialize section and the examples.
...	For initialize, any valid slots. For plot, passed to ggplot2::geom_line() for the plotting of the <i>cluster centroids</i> , or to stats::plot.hclust() . See Plotting section. For update, any supported argument. Otherwise ignored.

<code>override.family</code>	Logical. Attempt to substitute the default family with one that conforms to the provided elements? See Initialize section.
<code>object, x</code>	An object that inherits from <code>TSClusters</code> as returned by <code>tsclust()</code> .
<code>evaluate</code>	Logical. Defaults to TRUE and evaluates the updated call, which will result in a new <code>TSClusters</code> object. Otherwise, it returns the unevaluated call.
<code>newdata</code>	New data to be assigned to a cluster. It can take any of the supported formats of <code>tsclust()</code> . Note that for multivariate series, this means that it must be a list of matrices, even if the list has only one element.
<code>y</code>	Ignored.
<code>clus</code>	A numeric vector indicating which clusters to plot.
<code>labs.arg</code>	Arguments to change the title and/or axis labels. See <code>ggplot2::labs()</code> for more information
<code>series</code>	Optionally, the data in the same format as it was provided to <code>tsclust()</code> .
<code>time</code>	Optional values for the time axis. If series have different lengths, provide the time values of the longest series.
<code>plot</code>	Logical flag. You can set this to FALSE in case you want to save the ggplot object without printing anything to screen
<code>type</code>	What to plot. NULL means default. See details.

Details

The update method takes the original function call, replaces any provided argument and optionally evaluates the call again. Use `evaluate = FALSE` if you want to get the unevaluated call. If no arguments are provided, the object is updated to a new version if necessary (this is due to changes in the internal functions of the package, here for backward compatibility).

The predict generic can take the usual `newdata` argument and it returns the cluster(s) to which the data belongs; if NULL, it simply returns the obtained cluster indices. It preprocesses the data with the corresponding function if available.

Value

The plot method returns a gg object (or NULL for dendrogram plot) invisibly.

Initialize

The initialize method is used when calling `methods::new()`. The family slot can be substituted with an appropriate one if certain elements are provided by the user. The initialize methods of derived classes also inherit the family and can use it to calculate other slots. In order to get a fully functional object, at least the following slots should be provided:

- `type`: "partitional", "hierarchical", "fuzzy" or "tadpole".
- `datalist`: The data in one of the supported formats.
- `centroids`: The time series centroids in one of the supported formats.
- `cluster`: The cluster indices for each series in the `datalist`.

- `control*`: A [tsclust-controls](#) object with the desired parameters.
- `distance*`: A string indicating the distance that should be used.
- `centroid*`: A string indicating the centroid to use (only necessary for partitional clustering).

*Necessary when overriding the default family for the calculation of other slots, CVIs or prediction. Maybe not always needed, e.g. for plotting.

Plotting

The plot method uses the `ggplot2` plotting system (see [ggplot2::ggplot\(\)](#)).

The default depends on whether a hierarchical method was used or not. In those cases, the dendrogram is plotted by default; you can pass any extra parameters to [stats::plot.hclust\(\)](#) via `....`

Otherwise, the function plots the time series of each cluster along with the obtained centroid. The default values for cluster centroids are: `linetype = "dashed"`, `size = 1.5`, `colour = "black"`, `alpha = 0.5`. You can change this by means of `....`

You can choose what to plot with the `type` parameter. Possible options are:

- `"dendrogram"`: Only available for hierarchical clustering.
- `"series"`: Plot the time series divided into clusters without including centroids.
- `"centroids"`: Plot the obtained centroids only.
- `"sc"`: Plot both series and centroids

If created, the function returns the `gg` object invisibly, in case you want to modify it to your liking. You might want to look at [ggplot2::ggplot_build\(\)](#) if that's the case.

If you want to free the scale of the X axis, you can do the following:

```
plot(object, plot = FALSE) + facet_wrap(~cl, scales = "free")
```

Examples

```
data(uciCT)

# Assuming this was generated by some clustering procedure
centroids <- CharTraj[seq(1L, 100L, 5L)]
cluster <- unclass(CharTrajLabels)

pc_obj <- new("PartitionalTSClusters",
  type = "partitional", datalist = CharTraj,
  centroids = centroids, cluster = cluster,
  distance = "sbd", centroid = "dba",
  control = partitional_control(),
  args = tsclust_args(cent = list(window.size = 8L, norm = "L2")))

fc_obj <- new("FuzzyTSClusters",
  type = "fuzzy", datalist = CharTraj,
  centroids = centroids, cluster = cluster,
  distance = "sbd", centroid = "fcm",
```

```
control = fuzzy_control()

fc_obj
```

tsclustFamily-class *Class definition for tsclustFamily*

Description

Formal S4 class with a family of functions used in `tsclust()`.

Details

The custom implementations also handle parallelization.

Since the distance function makes use of proxy, it also supports any extra `proxy::dist()` parameters in ...

The prototype includes the `cluster` function for partitional methods, as well as a pass-through `preproc` function. The initializer expects a control from [tsclust-controls](#). See more below.

Slots

`dist` The function to calculate the distance matrices.

`allcent` The function to calculate centroids on each iteration.

`cluster` The function used to assign a series to a cluster.

`preproc` The function used to preprocess the data (relevant for `stats::predict()`).

Distance function

The `dist()` function in here works like `proxy::dist()` but supports parallelization and optimized symmetric calculations. If you like, you can use the function more or less directly, but provide a control argument when creating the family. However, bear in mind the following considerations.

- The second argument is call centroids (inconsistent with `proxy::dist()`).
- If `control$distmat` is *not* NULL, the function will try to subset it.
- If `control$symmetric` is TRUE, centroids is NULL, *and* there is no argument pairwise that is TRUE, only half the distance matrix will be computed.
 - If the distance was registered in `proxy::pr_DB` with `loop = TRUE` and more than one parallel worker is detected, the computation will be in parallel, otherwise it will be sequential with `proxy::dist()`.
- The function always returns a `crossdist` matrix.

Note that all distances implemented as part of **dtwclust** have custom proxy loops, so see their respective documentation to see what optimizations apply to each one.

For distances not included in **dtwclust**, the symmetric, parallel case mentioned above makes chunks for parallel workers, but they are not perfectly balanced, so some workers might finish before the others.

Centroid function

The default partitional `allcent()` function is a closure with the implementations of the included centroids. The ones for `DBA()` and `shape_extraction()` can use parallelization. Its formal arguments are described in the Centroid Calculation section from `tsclust()`.

Note

This class is meant to group together the relevant functions, but they are **not** linked with each other automatically. In other words, neither `dist` nor `allcent` apply `preproc`. They essentially don't know of each other's existence.

Examples

```
## Not run:
data(uciCT)
fam <- new("tsclustFamily", dist = "gak")

# This is done with symmetric optimizations, regardless of control$symmetric
crossdist <- fam@dist(CharTraj, window.size = 18L)

# This is done without symmetric optimizations, regardless of control$symmetric
crossdist <- fam@dist(CharTraj, CharTraj, window.size = 18L)

# For non-dtwclust distances, symmetric optimizations only apply
# with an appropriate control AND a single data argument:
fam <- new("tsclustFamily", dist = "dtw",
          control = partitional_control(symmetric = TRUE))
fam@dist(CharTraj[1L:5L])

## End(Not run)

# If you want the fuzzy family, use fuzzy = TRUE
ffam <- new("tsclustFamily", control = fuzzy_control(), fuzzy = TRUE)
```

tslist

Coerce matrices or data frames to a list of time series

Description

Change a matrix or data frame to a list of univariate time series

Usage

```
tslist(series)
```

Arguments

series A matrix or data frame where each row is a time series.

Details

Almost all functions in **dtwclust** work internally with lists of time series. If you want to avoid constant coercion, create a list of time series once by calling this function.

For matrices and data frames, each **row** is considered as one time series. A list input is simply passed through.

Value

A list of time series.

Note

The function assumes that indexing the matrix/data.frame with `series[i,]` will return a numeric vector.

uciCT

Subset of character trajectories data set

Description

Subset: only 5 examples of each considered character. See details.

Format

Lists with 100 elements each. Each element is a time series. Labels included as factor vector.

Details

Quoting the source:

"Multiple, labelled samples of pen tip trajectories recorded whilst writing individual characters. All samples are from the same writer, for the purposes of primitive extraction. Only characters with a single pen-down segment were considered."

The subset included in CharTraj has only 5 examples of the X velocity for each character. A vector with labels is also loaded in CharTrajLabels.

The subset included in CharTrajMV has 5 examples too, but includes tip force as well as X and Y velocity. Each element of the list is a multivariate series with 3 variables.

Please note that even though both CharTraj and CharTrajMV have the same series names, the actual series in each subset are **not** the same, i.e., CharTraj\$A.V1 is not in CharTrajMV\$A.V1.

Source

<https://archive.ics.uci.edu/ml/datasets/Character+Trajectories>

zscore

Wrapper for z-normalization

Description

Wrapper for function `base::scale()` that returns zeros instead of NaN. It also supports matrices, data frames, and lists of time series.

Usage

```
zscore(x, ..., multivariate = FALSE, keep.attributes = FALSE)
```

Arguments

x	Data to normalize. Either a vector, a matrix/data.frame where each row is to be normalized, or a list of vectors/matrices.
...	Further arguments to pass to <code>base::scale()</code> .
multivariate	Is x a multivariate time series? It will be detected automatically if a list is provided in x.
keep.attributes	Should the mean and standard deviation returned by <code>base::scale()</code> be preserved?

Details

Multivariate series must have time spanning the rows and variables spanning the columns.

Value

Normalized data in the same format as provided.

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