

Package ‘spatialsample’

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Title Spatial Resampling Infrastructure

Version 0.2.1

Description Functions and classes for spatial resampling to use with the 'rsample' package, such as spatial cross-validation (Brenning, 2012) <[doi:10.1109/IGARSS.2012.6352393](https://doi.org/10.1109/IGARSS.2012.6352393)>. The scope of 'rsample' and 'spatialsample' is to provide the basic building blocks for creating and analyzing resamples of a spatial data set, but neither package includes functions for modeling or computing statistics. The resampled spatial data sets created by 'spatialsample' do not contain much overhead in memory.

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URL <https://github.com/tidymodels/spatialsample>,
<https://spatialsample.tidymodels.org>

BugReports <https://github.com/tidymodels/spatialsample/issues>

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autoplot.spatial_rset *Create a ggplot for spatial resamples.*

Description

This method provides a good visualization method for spatial resampling.

Usage

```
## S3 method for class 'spatial_rset'
autoplot(object, ..., alpha = 0.6)

## S3 method for class 'spatial_block_cv'
autoplot(object, show_grid = TRUE, ..., alpha = 0.6)
```

Arguments

object	A <code>spatial_rset</code> object or a <code>spatial_rsplot</code> object. Note that only resamples made from <code>sf</code> objects create <code>spatial_rset</code> and <code>spatial_rsplot</code> objects; this function will not work for resamples made with non-spatial tibbles or data.frames.
...	Options passed to <code>ggplot2::geom_sf()</code> .
alpha	Opacity, passed to <code>ggplot2::geom_sf()</code> . Values of alpha range from 0 to 1, with lower values corresponding to more transparent colors.
show_grid	When plotting <code>spatial_block_cv</code> objects, should the grid itself be drawn on top of the data? Set to <code>FALSE</code> to remove the grid.

Details

The plot method for `spatial_rset` displays which fold each observation is assigned to. Note that if data is assigned to multiple folds (which is common if resamples were created with a non-zero radius) only the "last" fold for each observation will appear on the plot. Consider adding `ggplot2::facet_wrap(~ fold)` to visualize all members of each fold separately. Alternatively, consider plotting each split using the `spatial_rsplit` method (for example, via `lapply(object$splits, autoplot)`).

Value

A ggplot object with each fold assigned a color, made using `ggplot2::geom_sf()`.

Examples

```
boston_block <- spatial_block_cv(boston_canopy, v = 2)
autoplot(boston_block)
autoplot(boston_block$splits[[1]])
```

boston_canopy

Boston tree canopy and heat index data.

Description

A dataset containing data on tree canopy coverage and change for the city of Boston, Massachusetts from 2014-2019, as well as temperature and heat index data for July 2019. Data is aggregated to a grid of regular 25 hectare hexagons, clipped to city boundaries. This data is made available under the Public Domain Dedication and License v1.0 whose full text can be found at: <https://opendatacommons.org/licenses/pddl/1-0/>.

Usage

```
boston_canopy
```

Format

A data frame (of class `sf`, `tbl_df`, `tbl`, and `data.frame`) containing 682 records of 22 variables:

grid_id Unique identifier for each hexagon. Letters represent the hexagon's X position in the grid (ordered West to East), while numbers represent the Y position (ordered North to South).

land_area Area excluding water bodies

canopy_gain Area of canopy gain between the two years

canopy_loss Area of canopy loss between the two years

canopy_no_change Area of no canopy change between the two years

canopy_area_2014 2014 total canopy area (baseline)

- canopy_area_2019** 2019 total canopy area
- change_canopy_area** The change in area of tree canopy between the two years
- change_canopy_percentage** Relative change calculation used in economics is the gain or loss of tree canopy relative to the earlier time period: $(2019 \text{ Canopy} - 2014 \text{ Canopy}) / (2014 \text{ Canopy})$
- canopy_percentage_2014** 2014 canopy percentage
- canopy_percentage_2019** 2019 canopy percentage
- change_canopy_absolute** Absolute change. Magnitude of change in percent tree canopy from 2014 to 2019 ($\% 2019 \text{ Canopy} - \% 2014 \text{ Canopy}$)
- mean_temp_morning** Mean temperature for July 2019 from 6am - 7am
- mean_temp_evening** Mean temperature for July 2019 from 7pm - 8pm
- mean_temp** Mean temperature for July 2019 from 6am - 7am, 3pm - 4pm, and 7pm - 8pm (combined)
- mean_heat_index_morning** Mean heat index for July 2019 from 6am - 7am
- mean_heat_index_evening** Mean heat index for July 2019 from 7pm - 8pm
- mean_heat_index** Mean heat index for July 2019 from 6am - 7am, 3pm - 4pm, and 7pm - 8pm (combined)
- geometry** Geometry of each hexagon, encoded using EPSG:2249 as a coordinate reference system (NAD83 / Massachusetts Mainland (ftUS)). Note that the linear units of this CRS are in US feet.

Details

Note that this dataset is in the EPSG:2249 (NAD83 / Massachusetts Mainland (ftUS)) coordinate reference system (CRS), which may not be installed by default on your computer. Before working with `boston_canopy`, run:

- `sf::sf_proj_network(TRUE)` to install the CRS itself
- `sf::sf_add_proj_units()` to add US customary units to your units database

These steps only need to be taken once per computer (or per PROJ installation).

Source

Canopy data is from <https://data.boston.gov/dataset/hex-tree-canopy-change-metrics2>. Heat data is from <https://data.boston.gov/dataset/hex-mean-heat-index2>. Most field definitions are from <https://data.boston.gov/dataset/canopy-change-assessment-data-dictionary>.

spatial_block_cv *Spatial block cross-validation*

Description

Block cross-validation splits the area of your data into a number of grid cells, or "blocks", and then assigns all data into folds based on the blocks their centroid falls into.

Usage

```
spatial_block_cv(
  data,
  method = c("random", "snake", "continuous"),
  v = 10,
  relevant_only = TRUE,
  radius = NULL,
  buffer = NULL,
  ...
)
```

Arguments

data	An object of class <code>sf</code> or <code>sfc</code> .
method	The method used to sample blocks for cross validation folds. Currently supports "random", which randomly assigns blocks to folds, "snake", which labels the first row of blocks from left to right, then the next from right to left, and repeats from there, and "continuous", which labels each row from left to right, moving from the bottom row up.
v	The number of partitions for the resampling. Set to <code>NULL</code> or <code>Inf</code> for the maximum sensible value (for leave-one-X-out cross-validation).
relevant_only	For systematic sampling, should only blocks containing data be included in fold labeling?
radius	Numeric: points within this distance of the initially-selected test points will be assigned to the assessment set. If <code>NULL</code> , no radius is applied.
buffer	Numeric: points within this distance of any point in the test set (after radius is applied) will be assigned to neither the analysis or assessment set. If <code>NULL</code> , no buffer is applied.
...	Arguments passed to <code>sf::st_make_grid()</code> .

Details

The grid blocks can be controlled by passing arguments to `sf::st_make_grid()` via `...`. Some particularly useful arguments include:

- `cellsize`: Target cellsize, expressed as the "diameter" (shortest straight-line distance between opposing sides; two times the apothem) of each block, in map units.

- `n`: The number of grid blocks in the x and y direction (columns, rows).
- `square`: A logical value indicating whether to create square (TRUE) or hexagonal (FALSE) cells.

If both `cellsize` and `n` are provided, then the number of blocks requested by `n` of sizes specified by `cellsize` will be returned, likely not lining up with the bounding box of data. If only `cellsize` is provided, this function will return as many blocks of size `cellsize` as fit inside the bounding box of data. If only `n` is provided, then `cellsize` will be automatically adjusted to create the requested number of cells.

Value

A tibble with classes `spatial_block_cv`, `spatial_rset`, `rset`, `tbl_df`, `tbl`, and `data.frame`. The results include a column for the data split objects and an identification variable `id`.

References

D. R. Roberts, V. Bahn, S. Ciuti, M. S. Boyce, J. Elith, G. Guillera-Arroita, S. Hauenstein, J. J. Lahoz-Monfort, B. Schröder, W. Thuiller, D. I. Warton, B. A. Wintle, F. Hartig, and C. F. Dormann. "Cross-validation strategies for data with temporal, spatial, hierarchical, or phylogenetic structure," 2016, *Ecography* 40(8), pp. 913-929, doi: 10.1111/ecog.02881.

Examples

```
spatial_block_cv(boston_canopy, v = 3)
```

```
spatial_buffer_vfold_cv
```

V-Fold Cross-Validation with Buffering

Description

V-fold cross-validation (also known as k-fold cross-validation) randomly splits the data into V groups of roughly equal size (called "folds"). A resample of the analysis data consists of V-1 of the folds while the assessment set contains the final fold. These functions extend `rsample::vfold_cv()` and `rsample::group_vfold_cv()` to also apply an inclusion radius and exclusion buffer to the assessment set, ensuring that your analysis data is spatially separated from the assessment set. In basic V-fold cross-validation (i.e. no repeats), the number of resamples is equal to V.

Usage

```
spatial_buffer_vfold_cv(
  data,
  radius,
  buffer,
  v = 10,
```

```

    repeats = 1,
    strata = NULL,
    breaks = 4,
    pool = 0.1,
    ...
)

spatial_leave_location_out_cv(
  data,
  group,
  v = NULL,
  radius = NULL,
  buffer = NULL,
  ...
)

```

Arguments

<code>data</code>	A data frame.
<code>radius</code>	Numeric: points within this distance of the initially-selected test points will be assigned to the assessment set. If <code>NULL</code> , no radius is applied.
<code>buffer</code>	Numeric: points within this distance of any point in the test set (after radius is applied) will be assigned to neither the analysis or assessment set. If <code>NULL</code> , no buffer is applied.
<code>v</code>	The number of partitions for the resampling. Set to <code>NULL</code> or <code>Inf</code> for the maximum sensible value (for leave-one-X-out cross-validation).
<code>repeats</code>	The number of times to repeat the V-fold partitioning.
<code>strata</code>	A variable in <code>data</code> (single character or name) used to conduct stratified sampling. When not <code>NULL</code> , each resample is created within the stratification variable. Numeric <code>strata</code> are binned into quartiles.
<code>breaks</code>	A single number giving the number of bins desired to stratify a numeric stratification variable.
<code>pool</code>	A proportion of data used to determine if a particular group is too small and should be pooled into another group. We do not recommend decreasing this argument below its default of 0.1 because of the dangers of stratifying groups that are too small.
<code>...</code>	Not currently used.
<code>group</code>	A variable in <code>data</code> (single character or name) used to create folds. For leave-location-out CV, this should be a variable containing the locations to group observations by, for leave-time-out CV the time blocks to group by, and for leave-location-and-time-out the spatiotemporal blocks to group by.

Details

When `radius` and `buffer` are both `NULL`, `spatial_buffer_vfold_cv` is equivalent to `rsample::vfold_cv()` and `spatial_leave_location_out_cv` is equivalent to `rsample::group_vfold_cv()`.

References

K. Le Rest, D. Pinaud, P. Monestiez, J. Chadoeuf, and C. Bretagnolle. 2014. "Spatial leave-one-out cross-validation for variable selection in the presence of spatial autocorrelation," *Global Ecology and Biogeography* 23, pp. 811-820, doi: 10.1111/geb.12161.

H. Meyer, C. Reudenbach, T. Hengl, M. Katurji, and T. Nauss. 2018. "Improving performance of spatio-temporal machine learning models using forward feature selection and target-oriented validation," *Environmental Modelling & Software* 101, pp. 1-9, doi: 10.1016/j.envsoft.2017.12.001.

Examples

```
data(Smithsonian, package = "modeldata")
Smithsonian_sf <- sf::st_as_sf(
  Smithsonian,
  coords = c("longitude", "latitude"),
  crs = 4326
)

spatial_buffer_vfold_cv(
  Smithsonian_sf,
  buffer = 500,
  radius = NULL
)

data(ames, package = "modeldata")
ames_sf <- sf::st_as_sf(ames, coords = c("Longitude", "Latitude"), crs = 4326)
ames_neighborhoods <- spatial_leave_location_out_cv(ames_sf, Neighborhood)
```

spatial_clustering_cv *Spatial Clustering Cross-Validation*

Description

Spatial clustering cross-validation splits the data into V groups of disjointed sets by clustering points based on their spatial coordinates. A resample of the analysis data consists of $V-1$ of the folds/clusters while the assessment set contains the final fold/cluster.

Usage

```
spatial_clustering_cv(
  data,
  coords,
  v = 10,
  cluster_function = c("kmeans", "hclust"),
  radius = NULL,
  buffer = NULL,
```

```
    ...
  )
```

Arguments

data	A data frame or an sf object (often from <code>sf::read_sf()</code> or <code>sf::st_as_sf()</code>), to split into folds.
coords	A vector of variable names, typically spatial coordinates, to partition the data into disjointed sets via clustering. This argument is ignored (with a warning) if data is an sf object.
v	The number of partitions of the data set.
cluster_function	Which function should be used for clustering? Options are either "kmeans" (to use <code>stats::kmeans()</code>) or "hclust" (to use <code>stats::hclust()</code>). You can also provide your own function; see Details.
radius	Numeric: points within this distance of the initially-selected test points will be assigned to the assessment set. If NULL, no radius is applied.
buffer	Numeric: points within this distance of any point in the test set (after radius is applied) will be assigned to neither the analysis or assessment set. If NULL, no buffer is applied.
...	Extra arguments passed on to <code>stats::kmeans()</code> or <code>stats::hclust()</code> .

Details

Clusters are created based on either the distances between observations (if data is an sf object) or by clustering the variables in the coords argument. Each cluster is used as a fold for cross-validation. Depending on how the data are distributed spatially, there may not be an equal number of observations in each fold.

You can optionally provide a custom function to cluster_function. The function must take three arguments:

- dists, a `stats::dist()` object with distances between data points
- v, a length-1 numeric for the number of folds to create
- ..., to pass any additional named arguments to your function

The function should return a vector of cluster assignments of length `nrow(data)`, with each element of the vector corresponding to the matching row of the data frame.

Value

A tibble with classes `spatial_clustering_cv`, `spatial_rset`, `rset`, `tbl_df`, `tbl`, and `data.frame`. The results include a column for the data split objects and an identification variable `id`. Resamples created from non-sf objects will not have the `spatial_rset` class.

References

A. Brenning, "Spatial cross-validation and bootstrap for the assessment of prediction rules in remote sensing: The R package `sperrorest`," 2012 IEEE International Geoscience and Remote Sensing Symposium, Munich, 2012, pp. 5372-5375, doi: 10.1109/IGARSS.2012.6352393.

Examples

```
data(Smithsonian, package = "modeldata")
spatial_clustering_cv(Smithsonian, coords = c(latitude, longitude), v = 5)

smithsonian_sf <- sf::st_as_sf(
  Smithsonian,
  coords = c("longitude", "latitude"),
  # Set CRS to WGS84
  crs = 4326
)

# When providing sf objects, coords are inferred automatically
spatial_clustering_cv(smithsonian_sf, v = 5)

# Can use hclust instead:
spatial_clustering_cv(smithsonian_sf, v = 5, cluster_function = "hclust")
```

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