

Package ‘isocat’

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Type Package

Title Isotope Origin Clustering and Assignment Tools

Version 0.3.0

Description This resource provides tools to create, compare, and post-process spatial isotope assignment models of animal origin. It generates probability-of-origin maps for individuals based on user-provided tissue and environment isotope values (e.g., as generated by IsoMAP, Bowen et al. [2013] <[doi:10.1111/2041-210X.12147](https://doi.org/10.1111/2041-210X.12147)>) using the framework established in Bowen et al. (2010) <[doi:10.1146/annurev-earth-040809-152429](https://doi.org/10.1146/annurev-earth-040809-152429)>). The package 'isocat' can then quantitatively compare and cluster these maps to group individuals by similar origin. It also includes techniques for applying four approaches (cumulative sum, odds ratio, quantile only, and quantile simulation) with which users can summarize geographic origins and probable distance traveled by individuals. Campbell et al. [2020] establishes several of the functions included in this package <[doi:10.1515/ami-2020-0004](https://doi.org/10.1515/ami-2020-0004)>.

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clusterSimmatrix	<i>Hierarchical clustering analysis of similarity matrix</i>
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Description

Function applies hierarchical clustering analysis to similarity matrix, such as one output by 'simmatrixMaker' function. Just a wrapper for pvclust. Output is a pvclust object.

Usage

```
clusterSimmatrix(
  simmatrix,
  dist_mthd = "correlation",
  hclust_mthd = "average",
  nBoot = 1000,
  nClusters = FALSE,
  r = seq(0.7, 1.4, by = 0.1)
)
```

Arguments

simmatrix	symmetric similarity matrix object.
dist_mthd	Distance measure to be used. Defaults to "correlation". See help(pvclust).
hclust_mthd	Method of clustering. Defaults to "average". See help(pvclust).

nBoot number of bootstrap replications. Defaults to 1000. See help(pvclust).
nClusters number of clusters to run in parallel using 'doParallel'. Defaults to FALSE (non-parallel).
r Relative size of bootstrap replications.

Examples

```
# Create probability-of-origin maps to compare.
myiso <- rasterFromXYZ(isoscape)
raster::plot(myiso)
myiso_sd <- rasterFromXYZ(isoscape_sd)
n <- 5
set.seed(42)
df <- data.frame(
  ID = LETTERS[1:n],
  isotopeValue = sample(-120:-40, n),
  SD_indv = rep(5, n)
)
assignmentModels <- isotopeAssignmentModel(
  ID = df$ID,
  isotopeValue = df$isotopeValue,
  SD_indv = df$SD_indv,
  precip_raster = myiso,
  precip_SD_raster = myiso_sd,
  nClusters = FALSE
)
raster::plot(assignmentModels)
# Compare maps with simmatrixMaker.
mymatrix <- simmatrixMaker(assignmentModels, nClusters = FALSE, csvSavePath = FALSE)
# Cluster similarity matrix.
clust_results <- clusterSimmatrix(mymatrix, dist_mthd = "correlation",
  hclust_mthd = "average", nBoot = 1000, nClusters = FALSE,
  r = seq(.7,1.4,by=.1) )
clust_results
```

cumsumAtSamplingLocation

Cumulative sum at coordinates

Description

Function estimates cumulative sum of all values in a surface below the value at a specified longitude and latitude.

Usage

```
cumsumAtSamplingLocation(indivraster, Lat, Lon)
```

Arguments

indivraster	RasterLayer representing normalized probability of origin surface
Lat	Integer latitude
Lon	Integer longitude

See Also

[makecumsumSurface](#)

Examples

```
# Generate example probability surface.
myiso <- raster::rasterFromXYZ(isoscape)
myiso_sd <- rasterFromXYZ(isoscape_sd)
exampleSurface <- isotopeAssignmentModel(
  ID = "A",
  isotopeValue = -100,
  SD_indv = 5,
  precip_raster = myiso,
  precip_SD_raster = myiso_sd,
  nClusters = FALSE
)
# Calculate odds ratio at specific point.
set.seed(1)
x <- sample( which( !is.na(exampleSurface[]) ), size = 1)
pt <- raster::xyFromCell(exampleSurface, x)
cumsumAtSamplingLocation(indivraster = exampleSurface, Lat = pt[2], Lon = pt[1])
```

cumsumbelow

Cumulative sum below value

Description

Function that calculates the cumulative sum of values less than or equal to a given value.

Usage

```
cumsumbelow(vals)
```

Arguments

vals	Object of numeric or integer class.
------	-------------------------------------

Value

Returns list of values representing cumulative sum of ‘val’ values less than or equal to the input.

Examples

```
vals <- 1:10
cumsumbelow(vals)
```

getPrecisionPar	<i>Calculate model precision at given threshold values (in parallel).</i>
-----------------	---

Description

Function that counts cells (number and proportion) above given values.

Usage

```
getPrecisionPar(rasterstack, checkVals, method = FALSE, nCluster = 20)
```

Arguments

rasterstack	RasterStack of probability surfaces
checkVals	vector of numeric 'threshold' values against which to calculate precision
method	is FALSE by default. If character vector, appends a column recording 'method' used.
nCluster	is a numeric object specifying how many clusters to form and run in parallel.

Value

Returns a dataframe of precision values at given threshold.

isoscape	<i>Example isoscape data</i>
----------	------------------------------

Description

Example isoscape data

Usage

```
isoscape
```

Format

A dataframe containing 1800 observations, derived from a cropped raster object.

References

Campbell C. J. (2018) IsoMAP job 66100, Isoscapes Modeling, Analysis and Prediction (version 1.0). The IsoMAP Project. <http://isomap.org>

Bowen G. J., West J.B., Miller C. C., Zhao L. and Zhang T. (2018) IsoMAP: Isoscapes Modeling, Analysis and Prediction (version 1.0). IsoMAP job 66100, Caitlin J. Campbell. Isoscapes Modeling, Analysis and Prediction (version 1.0). The IsoMAP Project. <http://isomap.org>

Examples

```
iso <- rasterFromXYZ(isoscape)
```

isoscape_sd

Example isoscape standard deviation data

Description

Example isoscape standard deviation data

Usage

```
isoscape_sd
```

Format

A dataframe containing 1800 observations, derived from a cropped raster object.

References

Campbell C. J. (2018) IsoMAP job 66100, Isoscapes Modeling, Analysis and Prediction (version 1.0). The IsoMAP Project. <http://isomap.org>

Bowen G. J., West J.B., Miller C. C., Zhao L. and Zhang T. (2018) IsoMAP: Isoscapes Modeling, Analysis and Prediction (version 1.0). IsoMAP job 66100, Caitlin J. Campbell. Isoscapes Modeling, Analysis and Prediction (version 1.0). The IsoMAP Project. <http://isomap.org>

Examples

```
iso_sd <- rasterFromXYZ(isoscape_sd)
```

 isotopeAssignmentModel

Isotope assignment model function

Description

Creates isotope assignment models projections of probable origin. Results returned as a Raster-Stack, with layer names corresponding to individual ID.

Usage

```
isotopeAssignmentModel(
  ID,
  isotopeValue,
  SD_indv = 0,
  precip_raster,
  precip_SD_raster,
  additionalModels = FALSE,
  additionalModel_name = "CombinedIsotope-OtherModelAssignments",
  savePath = FALSE,
  nClusters = FALSE
)
```

Arguments

ID	ID value or vector of values (for naming assignment model layers). If missing, will count from 1.
isotopeValue	Isotope precipitation value or vector of values.
SD_indv	error associated with transfer function fit. Value or vector of values. If missing, will assume value of 0.
precip_raster	precipitation isoscape raster.
precip_SD_raster	precipitation isoscape standard deviation raster.
additionalModels	optional additional model raster object (e.g. an SDM, rasterized range map, or stack thereof). If specified, function will return isotope assignment rasters and the product of these additionalModels and each assignmentRaster.
additionalModel_name	optional filename for additionalModel .grd savepath
savePath	If specified, function will save results to this path as a '.grd' file.
nClusters	integer of cores to run in parallel with doParallel. Default FALSE.

Examples

```

myiso <- rasterFromXYZ(isoscape)
raster::plot(myiso)
myiso_sd <- rasterFromXYZ(isoscape_sd)
df <- data.frame(
  ID = paste0("Example.", 1:3),
  isotopeValue = c(-100, -80, -50),
  SD_indv = rep(5, 3)
)
assignmentModels <- isotopeAssignmentModel(
  ID = df$ID,
  isotopeValue = df$isotopeValue,
  SD_indv = df$SD_indv,
  precip_raster = myiso,
  precip_SD_raster = myiso_sd
)
raster::plot(assignmentModels)

# Add additionalModels:
range_raster <- myiso
range_raster[] <- as.numeric( 1:ncell(myiso) %% 60 >= 10)
plot(range_raster)

sdm_raster <- myiso
sdm_raster[] <- (1:ncell(sdm_raster))^2
sdm_raster <- sdm_raster / raster::cellStats(sdm_raster, "sum")
plot(sdm_raster)

extraModels <- raster::stack(range_raster, sdm_raster)
assignmentModels <- isotopeAssignmentModel(
  ID = paste0("Combo.",df$ID),
  isotopeValue = df$isotopeValue,
  SD_indv = df$SD_indv,
  precip_raster = myiso,
  precip_SD_raster = myiso_sd,
  additionalModels = extraModels
)
raster::plot(assignmentModels)

```

makecumsumSurface

Create cumulative sum probability surface

Description

Converts normalized probability surface (e.g. one layer output of `isotopeAssignmentModel` function) to cumulative sum surfaces, i.e., one where the new value of a given cell is equal to the sum of all old values less than or equal to the old value of the cell.

Usage

```
makecumsumSurface(indivraster, rescale = FALSE, rename = FALSE)
```

Arguments

`indivraster` Normalized probability surface RasterLayer

`rescale` Rescale between 0 and 1? Defaults to FALSE.

`rename` Character value to append to raster name (e.g. "_odds"). Defaults to FALSE.

Value

Returns RasterLayer rescaled to Cumulative Sum values.

See Also

[cumsumAtSamplingLocation](#)

Examples

```
# Generate example probability surfaces.
myiso <- rasterFromXYZ(isoscape)
myiso_sd <- rasterFromXYZ(isoscape_sd)
df <- data.frame(
  ID = c(-100, -80, -50),
  isotopeValue = c(-100, -80, -50),
  SD_indv = rep(5, 3)
)
assignmentModels <- isotopeAssignmentModel(
  ID = df$ID,
  isotopeValue = df$isotopeValue,
  SD_indv = df$SD_indv,
  precip_raster = myiso,
  precip_SD_raster = myiso_sd,
  nClusters = FALSE
)

# Convert to cumulative sum surface.
cumulative_sum_surface <- stack(
  lapply( unstack( assignmentModels ), makecumsumSurface )
)
plot(cumulative_sum_surface)
```

makeMultiMonthIsoscape

Make mean multi-month isoscape and error surfaces.

Description

Converts a stack of monthly isoscape maps, monthly isoscape standard error maps, and optionally a precipitation (amount) stack. Each stack must contain layers corresponding to each of the target months.

Usage

```
makeMultiMonthIsoscape(iso_stack, iso_se_stack, precip_stack = NULL)
```

Arguments

iso_stack	A RasterStack containing n layers corresponding to isoscape models for n months.
iso_se_stack	A RasterStack containing n layers corresponding to isoscape standard error maps for n months.
precip_stack	Either a RasterStack containing n layers corresponding to precipitation amounts for n months, or NULL (assumes equal precipitation amounts.)

Details

If precip_stack is NULL, model will assume equal precipitation amounts per month.

Value

A list containing a mean isoscape and root-sum-of-square error map

makeOddsSurfaces

Convert probability surface to odds-ratio surface

Description

Converts normalized probability surface (e.g. one layer output of isotopeAssignmentModel function) to Odds Ratio surfaces.

Usage

```
makeOddsSurfaces(probabilitySurface, rename = FALSE)
```

Arguments

probabilitySurface Normalized probability surface RasterLayer
rename Character value to append to raster name (e.g. "_odds"). Defaults to FALSE.

Value

Returns RasterLayer rescaled to Odds Ratio values.

See Also

[oddsAtSamplingLocation](#)

Examples

```
# Generate example probability surfaces.
myiso <- rasterFromXYZ(isoscape)
myiso_sd <- rasterFromXYZ(isoscape_sd)
df <- data.frame(
  ID = c(-100, -80, -50),
  isotopeValue = c(-100, -80, -50),
  SD_indv = rep(5, 3)
)
assignmentModels <- isotopeAssignmentModel(
  ID = df$ID,
  isotopeValue = df$isotopeValue,
  SD_indv = df$SD_indv,
  precip_raster = myiso,
  precip_SD_raster = myiso_sd,
  nClusters = FALSE
)

# Convert to odds ratio surfaces.
odds_ratio_surface <- stack(
  lapply( unstack(assignmentModels), makeOddsSurfaces )
)
plot(odds_ratio_surface)
```

makeQuantileSimulationSurface

Create quantile-simulation surfaces

Description

Converts normalized probability surfaces (e.g. one layer output of isotopeAssignmentModel function) to quantile surfaces.

Usage

```
makeQuantileSimulationSurface(
  probabilitySurface,
  ValidationQuantiles,
  rename = FALSE,
  rescale = TRUE
)
```

Arguments

probabilitySurface	Normalized probability surface RasterLayer.
ValidationQuantiles	Vector of quantile values from known-origin individuals, against which to compare each value within the probability surface. Each value must be between 0 and 1.
rename	Character value to append to raster name (e.g. "_quantileSimulation"). Defaults to FALSE.
rescale	If rescale = TRUE, returns surface showing proportion of times each surface cell value fell within the validation quantiles distribution. If rescale = FALSE, returns discrete number of times the cell fell within the distribution.

Value

Returns RasterLayer rescaled to quantile values.

Examples

```
# Generate example probability surfaces.
library(isocat)
myiso <- raster::rasterFromXYZ(isoscape)
myiso_sd <- raster::rasterFromXYZ(isoscape_sd)
df <- data.frame(
  ID = c(-100, -80, -50),
  isotopeValue = c(-100, -80, -50),
  SD_indv = rep(5, 3)
)
assignmentModels <- isotopeAssignmentModel(
  ID = df$ID,
  isotopeValue = df$isotopeValue,
  SD_indv = df$SD_indv,
  precip_raster = myiso,
  precip_SD_raster = myiso_sd
)

# Example known-origin quantile data.
q <- rweibull(20000, 6, .98)
q <- sample( q[ q >= 0 & q <= 1 ], 10000, replace = TRUE)
hist(q)
```

```
# Convert to quantile surfaces.
quantileSimulation_surface <- raster::stack(
  lapply(
    unstack(assignmentModels),
    makeQuantileSimulationSurface,
    ValidationQuantiles = q)
  )
plot(quantileSimulation_surface)
```

makeQuantileSurfaces *Convert probability surface to probability-quantile surface*

Description

Converts normalized probability surface (e.g. one layer output of `isotopeAssignmentModel` function) to quantile surfaces.

Usage

```
makeQuantileSurfaces(probabilitySurface, rename = FALSE)
```

Arguments

`probabilitySurface`
Normalized probability surface `RasterLayer`

`rename`
Character value to append to raster name (e.g. `"_quantile"`). Defaults to `FALSE`.

Value

Returns `RasterLayer` rescaled to quantile values.

See Also

[quantileAtSamplingLocation](#)

Examples

```
# Generate example probability surfaces.
myiso <- rasterFromXYZ(isoscape)
myiso_sd <- rasterFromXYZ(isoscape_sd)
df <- data.frame(
  ID = c(-100, -80, -50),
  isotopeValue = c(-100, -80, -50),
  SD_indv = rep(5, 3)
)
assignmentModels <- isotopeAssignmentModel(
  ID = df$ID,
  isotopeValue = df$isotopeValue,
```

```

SD_indv = df$SD_indv,
precip_raster = myiso,
precip_SD_raster = myiso_sd,
nClusters = FALSE
)

# Convert to quantile surfaces.
quantile_surface <- raster::stack( lapply( unstack(assignmentModels), makeQuantileSurfaces) )
plot(quantile_surface)

```

meanAggregateClusterProbability

Create mean aggregate probability-of-origin surfaces for each cluster.

Description

Subset probability-of-origin surfaces by cluster assignment and find mean aggregate probability-of-origin surface for each clustered group.

Usage

```
meanAggregateClusterProbability(indivIDs, clusters, surfaces, nClust = FALSE)
```

Arguments

indivIDs	Vector of individual ID variables corresponding to surface names.
clusters	Vector of cluster IDs, in an order corresponding to 'indivIDs'.
surfaces	Stack of probability-of-origin surfaces for all individuals. Object of class 'RasterStack.'
nClust	Create and apply a multi-core cluster for faster processing using 'raster' and 'parallel' packages. Defaults to 'FALSE' (i.e., no clustering).

Examples

```

# Create and cluster example assignment surfaces.
myiso <- rasterFromXYZ(isoscape)
myiso_sd <- rasterFromXYZ(isoscape_sd)
df <- data.frame(
  ID = LETTERS[1:9],
  isotopeValue = seq(-120, -25, length.out = 9),
  SD_indv = rep(5, 9)
)
assignmentModels <- isotopeAssignmentModel(
  ID = df$ID,
  isotopeValue = df$isotopeValue,
  SD_indv = df$SD_indv,

```

```

        precip_raster = myiso,
        precip_SD_raster = myiso_sd,
        nClusters = FALSE
    )
mySimilarityMatrix <- simmatrixMaker(assignmentModels)
cS <- clusterSimmatrix(
    simmatrix = mySimilarityMatrix,
    r = seq(.7,1.4,by=.1)
)
# Cut clusters.
myheight <- 0.25
df$cluster <- dendextend::cutree(cS$hclust, h = myheight)
# Create mean aggregate surfaces.r p
meanSurfaces <- meanAggregateClusterProbability(
    indivIDs = df$ID,
    clusters = df$cluster,
    surfaces = assignmentModels,
    nClust = FALSE
)

```

oddsAtSamplingLocation

Odds ratio at coordinates function

Description

Function estimates percentile of each non-NA value within a RasterLayer using the empirical cumulative distribution function, and extracts value at location specified. For more information, see `help(ecdf)`.

Usage

```
oddsAtSamplingLocation(indivraster, Lat, Lon)
```

Arguments

indivraster	RasterLayer representing normalized probability of origin surface
Lat	Integer latitude
Lon	Integer longitude

See Also

[makeOddsSurfaces](#)

Examples

```
# Generate example probability surface.
myiso <- raster::rasterFromXYZ(isoscape)
myiso_sd <- rasterFromXYZ(isoscape_sd)
exampleSurface <- isotopeAssignmentModel(
  ID = "A",
  isotopeValue = -100,
  SD_indv = 5,
  precip_raster = myiso,
  precip_SD_raster = myiso_sd,
  nClusters = FALSE
)
# Calculate odds ratio at specific point.
set.seed(1)
x <- sample( which( !is.na(exampleSurface[]) ), size = 1)
pt <- raster::xyFromCell(exampleSurface, x)
oddsAtSamplingLocation(exampleSurface, Lat = pt[2], Lon = pt[1])
```

projectSummaryMaxSurface

Project probability-of-origin surfaces into one summary surface.

Description

Create a summary surface showing which RasterLayer in a Stack has the highest value at a given location. For each cell in a RasterStack, this function returns the identity of the RasterLayer with the highest value at that cell. This surface is intended as a visual summary of common origins, not a basis for quantitative analysis.

Usage

```
projectSummaryMaxSurface(surfaces, nClust = FALSE)
```

Arguments

surfaces	Object of class "RasterStack", where each layer represents a probability-of-origin surface
nClust	Create and apply a multi-core cluster for faster processing using 'raster' and 'parallel' packages. Defaults to 'FALSE' (i.e., no clustering).

Examples

```
# Create and cluster example assignment surfaces.
myiso <- rasterFromXYZ(isoscape)
myiso_sd <- rasterFromXYZ(isoscape_sd)
assignmentModels <- isotopeAssignmentModel(
  ID = LETTERS[1:4],
```



```

        isotopeValue = seq(-120,-25,length.out = 4),
        SD_indv = rep(5,4),
        precip_raster = myiso,
        precip_SD_raster = myiso_sd,
        nClusters = FALSE
    )
raster::plot(assignmentModels)

# Project mean aggregate surfaces into space.
summaryMap <- projectSummaryMaxSurface(
    surfaces = assignmentModels,
    nClust = FALSE
)
raster::plot(summaryMap)

```

quantileAtSamplingLocation

Quantile at coordinates function

Description

Function estimates percentile of each non-NA value within a RasterLayer using the empirical cumulative distribution function, and extracts value at location specified. For more information, see `help(ecdf)`.

Usage

```
quantileAtSamplingLocation(indivraster, Lat, Lon)
```

Arguments

indivraster	A RasterLayer representing normalized probability of origin surface
Lat	Integer latitude
Lon	Integer longitude

See Also

[makeQuantileSurfaces](#)

Examples

```

# Generate example probability surface.
myiso <- raster::rasterFromXYZ(isoscape)
myiso_sd <- rasterFromXYZ(isoscape_sd)
exampleSurface <- isotopeAssignmentModel(
    ID = "A",
    isotopeValue = -100,
    SD_indv = 5,

```

```

      precip_raster = myiso,
      precip_SD_raster = myiso_sd,
      nClusters = FALSE
    )
# Calculate quantile probability value at specific point.
set.seed(1)
x <- sample( which( !is.na(exampleSurface[]) ), size = 1)
pt <- raster::xyFromCell(exampleSurface, x)
quantileAtSamplingLocation(exampleSurface, Lat = pt[2], Lon = pt[1])

```

schoenersD

Calculates Schoener's D-value between two RasterLayers.

Description

RasterLayers must have identical resolutions and extents. The function will automatically normalize surfaces to sum to 1.

Usage

```
schoenersD(rast1, rast2)
```

Arguments

rast1	Input RasterLayer
rast2	Input RasterLayer 2

Details

Calculates similarity value of two RasterLayers using Schoener's D-metric.

Examples

```

# Generate example probability surfaces.
myiso <- raster::rasterFromXYZ(isoscape)
myiso_sd <- raster::rasterFromXYZ(isoscape_sd)
df <- data.frame(
  ID = c(-100, -80, -50),
  isotopeValue = c(-100, -80, -50),
  SD_indv = rep(5, 3)
)
assignmentModels <- isotopeAssignmentModel(
  ID = df$ID,
  isotopeValue = df$isotopeValue,
  SD_indv = df$SD_indv,
  precip_raster = myiso,
  precip_SD_raster = myiso_sd,

```

```

        nClusters = FALSE
      )

# Calculate Schoener's D-metric of spatial similarity between two of the
# example probability surfaces.
schoenersD(assignmentModels[[1]], assignmentModels[[2]])
## 0.969156

```

simmatrixMaker

Generates similarity matrix for RasterStack

Description

Applies pairwise comparisons of Schoener's D-metric between each RasterLayer in a RasterStack to populate a similarity matrix.

Usage

```
simmatrixMaker(assignmentRasters, nClusters = FALSE, csvSavePath = FALSE)
```

Arguments

assignmentRasters	Input RasterStack
nClusters	Clusters to create run in parallel using 'doParallel'. Defaults to FALSE.
csvSavePath	Optional savepath to write similarity matrix to csv file. Defaults to FALSE, will not create csv.

Examples

```

# Create probability-of-origin maps to compare.
myiso <- rasterFromXYZ(isoscape)
raster::plot(myiso)
myiso_sd <- rasterFromXYZ(isoscape_sd)
n <- 5
set.seed(42)
df <- data.frame(
  ID = LETTERS[1:n],
  isotopeValue = sample(-120:-40, n),
  SD_indv = rep(5, n)
)
assignmentModels <- isotopeAssignmentModel(
  ID = df$ID,
  isotopeValue = df$isotopeValue,
  SD_indv = df$SD_indv,
  precip_raster = myiso,
  precip_SD_raster = myiso_sd,
  nClusters = FALSE
)

```

```
    )  
raster::plot(assignmentModels)  
# Compare maps with simmatrixMaker.  
simmatrixMaker(assignmentModels, nClusters = FALSE, csvSavePath = FALSE)
```

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