Package 'rcarbon'

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Title Calibration and Analysis of Radiocarbon Dates

Version 1.2.0

Description Enables the calibration and analysis of radiocarbon dates, often but not exclusively for the purposes of archaeological research. It includes functions not only for basic calibration, uncalibration, and plotting of one or more dates, but also a statistical framework for building demographic and related longitudinal inferences from aggregate radiocarbon date lists, including: Monte-Carlo simulation test (Timpson et al 2014 <doi:10.1016/j.jas.2014.08.011>), random mark permutation test (Crema et al 2016 <doi:10.1371/journal.pone.0154809>) and spatial permutation tests (Crema, Bevan, and Shennan 2017 <doi:10.1016/j.jas.2017.09.007>).

Depends R (>= 3.3.1)

Imports sp,stats,graphics,grDevices,utils,doParallel,foreach,parallel,knitr

Suggests

License GPL (>= 2)

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LazyData true

VignetteBuilder knitr

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NeedsCompilation no

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R topics documented:

`as.CalGrid` *Convert data to class CalGrid.*

Description

Tries to coerce any two-column matrix or data.frame to a calibrated probability distribution (an object of class "CalGrid") for use by the rcarbon package.

Usage

```
as.CalGrid(x)
```

Arguments

x	A two-column matrix or data.frame class object.

Value

A CalGrid class object of probabilities or summed probabilities per calendar year BP.

Examples

```
df <- data.frame(calBP=5000:2000,PrDens=runif(length(5000:2000)))
mycalgrid <- as.CalGrid(df)
plot(mycalgrid)
```

---

barCodes *Plot the median values of calibrated radiocarbon dates or bins*

Description

Plot the median values of multiple calibrated radiocarbon dates or bins in a barcode-like strip.

Usage

```
barCodes(x, yrng = c(0, 0.03), width = 20, col = rgb(0, 0, 0, 25,
  maxColorValue = 255), border = NA, ...)
```

Arguments

x	A vector containing median values obtained from medCal or binMed
yrng	y-axis range of the bars.
width	width of the bars (optional)
col	color of the bars
border	the color to draw the border. Use border = NA to omit borders.
...	Additional arguments affecting the plot

See Also

medCal; binMed

Examples

```
## Not run:
#Load EUROEVOL Data
data(euroevol)

#Subset Danish Dates
denmark <- subset(euroevol,Country=="Denmark")

#Calibrate and Bin
denmarkDates <- calibrate(x=denmark$C14Age,errors=denmark$C14SD)
denmarkBins <- binPrep(sites=denmark$SiteID,ages=denmark$C14Age,h=200) #200 years bin size

#Compute median date for each bin
bm <- binMed(x=denmarkDates,bins=denmarkBins)

#Compute median date for each date
dm <- medCal(denmarkDates)

#Compute SPD
denmarkSPD <- spd(x=denmarkDates,bins=denmarkBins,timeRange=c(10000,4000))

#Plot SPD and barCodes of median dates
plot(denmarkSPD,runm=200)
barCodes(dm,yrng=c(0,0.01))

#Plot SPD and barCodes of median bins in BC/AD
plot(denmarkSPD,runm=200,calendar="BCAD")
barCodes(BPtoBCAD(bm),yrng=c(0,0.01))

## End(Not run)
```

BCADtoBP *Convert BC/AD dates to BP format*

Description

Converts BC/AD dates to BP format while handling the absence of 'year 0'

Usage

```
BCADtoBP(x)
```

Arguments

x	A numerical vector (currently no checks that these numbers are in a sensible range).

Value

A vector with BC/BCE dates expressed as negative numbers and AD/CE dates as positive ones.

Examples

```
BCADtoBP(-1268)
```

`binMed` *Computes the median date of each bin*

Description

Function for generating a vector of median calibrated dates for each each bin.

Usage

```
binMed(x, bins, verbose = TRUE)
```

Arguments

`x`	A `CalDates` class object.
`bins`	vector containing the bin names associated with each radiocarbon date. Can be generated using `binPrep`.
`verbose`	A logical variable indicating whether extra information on progress should be reported. Default is TRUE.

Value

A vector of median dates in cal BP

See Also

`binPrep`,`barCodes`

Examples

```
## Not run:
#Load EUROEVOL Data
data(euroevol)
#Subset Danish Dates
denmark <- subset(euroevol,Country=="Denmark")
#Calibrate and Bin
denmarkDates <- calibrate(x=denmark$C14Age,errors=denmark$C14SD)
denmarkBins <- binPrep(sites=denmark$SiteID,ages=denmark$C14Age,h=200) #200 years bin size
#Compute median date for each bin
binMed(x=denmarkDates,bins=denmarkBins)

## End(Not run)
```

binPrep *Binning function of radiocarbon dates.*

Description

Prepare a set of bins for controlling the aggregation of radiocarbon dates known to be from the same phase of same archaeological site (for use with spd). Used in cases where there is a concern that unusually high levels of sampling for radiocarbon at a given site or in a given site phase will impede comparison between sites or phases.

Usage

```
binPrep(sites, ages, h)
```

Arguments

sites	a vector of character strings (or number to coerce to character) of all sites or site phases
ages	a vector of uncalibrated conventional radiocarbon ages or a CalDates class object obtained using the calibrate function.
h	a single numeric value passed to hclust control degree of grouping of similar ages in a phase site.

Details

If ages is a CalDates class object, median dates are used for the clustering.

Value

A vector of character strings with the same length of the object supplied for the argument ages identifying intra-site or intra-phase grouping, for use with spd

See Also

spd for generating SPD; binsense for sensitivity analysis pertaining the choice of the parameter h.

binsense *Bin sensitivity Plot*

Description

Visually explores how choosing different values for h in the binPrep function affects the shape of the SPD.

Usage

```
binsense(x, y, h, timeRange, calendar = "BP", binning = "CRA",
  raw = F, verbose = T, legend = T, ...)
```

Arguments

x	A CalDates class object containing calibrated radiocarbon dates.
y	A vector containing the locations ID (e.g. site ID) of each calibrated date to be used for the binning process.
h	A vector of numbers containing values for the h parameter to be used in the binPrep function.
timeRange	A vector of length 2 indicating the start and end date of the analysis in cal BP.
calendar	Either 'BP' or 'BCAD'. Indicate whether the calibrated date should be displayed in BP or BC/AD. Default is 'BP'.
binning	Either 'CRA' or 'calibrated'. Indicate whether the binning should be carried usinig the 14C age or using the median calibrated date. Default is 'CRA'.
raw	A logical variable indicating whether all SPDs should be returned or not. Default is FALSE.
verbose	A logical variable indicating whether extra information on progress should be reported. Default is TRUE.
legend	A logical variable indicating whether the legend should be displayed. Default is TRUE
...	Additional arguments to be passed to the spd function.

See Also

binPrep; spd

Examples

```
## Not run:
data(euroevol)
#subset Danish dates
denmark=subset(euroevol,Country=="Denmark")
denmarkDates=calibrate(x=denmark$C14Age,errors=denmark$C14SD)
binsense(x=denmarkDates,y=denmark$SiteID,h=seq(0,200,20),timeRange=c(10000,4000),runm=200)

## End(Not run)
```

BPtoBCAD *Convert BP dates to BC/AD format*

Description

Converts calibrated BP dates to BC/AD dates, omitting 'year 0'

Usage

```
BPtoBCAD(x)
```

Arguments

x	A numerical vector (currently no checks that these numbers are in a sensible range).

Value

A vector with BC/BCE dates expressed as negative numbers and AD/CE dates as positive ones.

Examples

```
BPtoBCAD(4200)
```

calibrate *Calibrate radiocarbon dates*

Description

Function for calibrating one or more radiocarbon dates.

Usage

```
calibrate(x, ...)

## Default S3 method:
calibrate(x, errors, ids = NA, dateDetails = NA,
  calCurves = "intcal13", resOffsets = 0, resErrors = 0,
  timeRange = c(50000, 0), normalised = TRUE, calMatrix = FALSE,
  eps = 1e-05, ncores = 1, verbose = TRUE, ...)
```

Arguments

x	A vector of uncalibrated radiocarbon ages .
...	ignored
errors	A vector of standard deviations corresponding to each estimated radiocarbon age.
ids	An optional vector of IDs for each date.
dateDetails	An optional vector of details for each date which will be returned in the output metadata.
calCurves	Either a character string naming a calibration curve already provided with the rcarbon package (currently 'intcal13','intcal13nhpine16','shcal13','shcal13shkauri16','marine13' and 'normal'(i.e. no calibration) are possible; default is 'intcal13') or a custom calibration curve as three-column matrix or data.frame (calibrated year BP, uncalibrated age bp, standard deviation). Different existing curves can be specified per dated sample, but only one custom curve can be provided for all dates.
resOffsets	A vector of offset values for any marine reservoir effect (default is no offset).
resErrors	A vector of offset value errors for any marine reservoir effect (default is no offset).
timeRange	Earliest and latest data to calibrate for, in calendar years. Posterior probabilities beyond this range will be excluded (the default is sensible in most cases).
normalised	A logical variable indicating whether the calibration should be normalised or not. Default is TRUE.
calMatrix	a logical variable indicating whether the age grid should be limited to probabilities higher than eps
eps	Cut-off value for density calculation. Default is 1e-5.
ncores	Number of cores/workers used for parallel execution. Default is 1 (>1 requires doParallel package).
verbose	A logical variable indicating whether extra information on progress should be reported. Default is TRUE.

Details

This function computes one or more calibrated radiocarbon ages using the method described in Bronk Ramsey 2008 (albeit not in F14C space, see also Parnell 2017). It is possible to specify different calibration curves or reservoir offsets individually for each date, and control whether the resulting calibrated distribution is normalised to 1 under-the-curve or not. Calculations can also be executed in parallel to reduce computing time. The function was modified from the BchronCalibrate function in the Bchron package developed by A.Parnell (see references below).

Value

An object of class CalDates with the following elements:

- metadata A data.frame containing relevant information regarding each radiocarbon date and the parameter used in the calibration process.

- `grids` A list of calGrid class objects, containing the posterior probabilities for each calendar year. The most memory-efficient way to store calibrated dates, as only years with non-zero probability are stored, but aggregation methods such as `spd()` may then take longer to extract and combine multiple dates. NA when the parameter calMatrix is set to TRUE.
- `calMatrix` A matrix of probability values, one row per calendar year in timeRange and one column per date. By storing all possible years, not just those with non-zero probability, this approach takes more memory, but speeds up spd() and is suggested whenever the latter is to be used. NA when the parameter calMatrix is set to FALSE.

References

Bronk Ramsey, C. 2008. Radiocarbon dating: revolutions in understanding, *Archaeometry* 50.2: 249-75. DOI: https://doi.org/10.1111/j.1475-4754.2008.00394.x
Parnell, A. 2017. Bchron: Radiocarbon Dating, Age-Depth Modelling, Relative Sea Level Rate Estimation, and Non-Parametric Phase Modelling, R package: https://CRAN.R-project.org/package=Bchron

Examples

```
x1 <- calibrate(x=4000, errors=30)
plot(x1)
summary(x1)
# Example with a Marine Date, using a DeltaR of 300 and a DeltaR error of 30
x2 <- calibrate(x=4000, errors=30, calCurves='marine13', resOffsets=300, resErrors=30)
plot(x2)
```

---

emedyd

Radiocarbon dates for the Eastern Mediterranean around the Younger Dryas

---

Description

Radiocarbon dates (n=1915) and site coordinates (n=201) from a paper considering the relationship between human activity in the eastern Mediterranean/Middle East and early Holocene climate change, including the Younger Dryas.

Usage

```
emedyd
```

Format

A data.frame with the following variables:

`LabID` Laboratory ID assigned to each radiocarbon date (where known)

`CRA` Radiocarbon age in 14C years BP

`Error` Radiocarbon age error

`Material` Material of the dated sample

`Species` Species of the dated sample (where identified)

`SiteName` Name of the site from which the sample has been recovered

`Country` Country where the sampling site is located

`Longitude` Longitude of the sampling site in decimal degrees

`Latitude` Latitude of the sampling site in decimal degrees

`Region` One of three analytical regions (1=southern Levant, 2=Northern Levant, 3= South-central Anatolia

Source

Palmisano, A., Bevan, A. and S. Shennan 2017. Data and code for demographic trends in the paper "Human responses and non-responses to climatic variations during the Last Glacial-Interglacial transition in the eastern Mediterranean", UCL Discovery Archive 1570274. doi:10.14324/000.ds.1570274.

References

Roberts, N., Woodbridge, J., Bevan, A., Palmisano, A., Shennan, S. and E. Asouti 2017. Human responses and non-responses to climatic variations during the Last Glacial-Interglacial transition in the eastern Mediterranean. Quaternary Science Reviews, 184, 47-67. doi:10.1016/j.quascirev.2017.09.011.

Examples

```
## Not run:
data(emedyd)
northernlevant <- emedyd[emedyd$Region=="2",]
bins <- binPrep(northernlevant$SiteName, northernlevant$CRA, h=50)
x <- calibrate(northernlevant$CRA, northernlevant$Error, normalised=FALSE)
spd.northernlevant <- spd(x, bins=bins, runm=50, timeRange=c(17000,8000))
plot(spd.northernlevant)

## End(Not run)
```

`euroevol` *Radiocarbon dates from the EUROEVOL database*

Description

Radiocarbon dates (n=14,053) and site coordinates (n=4,213) from the EUROEVOL project database. Sites without radiocarbon dates (n=544), phase-codes, and other data have been omitted (the complete dataset can be found on http://discovery.ucl.ac.uk/1469811/).

Usage

```
euroevol
```

Format

A data.frame with the following variables:

`C14ID` ID of each radiocarbon date

`C14Age` Radiocarbon age in 14C years BP

`C14SD` Radiocarbon age error

`LabCode` Labcode of the radiocarbon date

`Material` Material of the dated sample

`SiteID` ID of the site from which the sample has been recovered

`Latitude` Latitude of the sampling site in decimal degrees

`Longitude` Longitude of the sampling site in decimal degrees

`Country` Country where the sampling site is located

Source

Manning, K., Colledge, S., Crema, E., Shennan, S., Timpson, A., 2016. The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset 1: Sites, Phases and Radiocarbon Data. Journal of Open Archaeology Data 5. doi:10.5334/joad.40

References

Shennan, S., Downey, S.S., Timpson, A., Edinborough, K., Colledge, S., Kerig, T., Manning, K., Thomas, M.G., 2013. Regional population collapse followed initial agriculture booms in mid-Holocene Europe. Nature Communications 4, ncomms3486. doi:10.1038/ncomms3486

Timpson, A., Colledge, S., Crema, E., Edinborough, K., Kerig, T., Manning, K., Thomas, M.G., Shennan, S., 2014. Reconstructing regional population fluctuations in the European Neolithic using radiocarbon dates: a new case-study using an improved method. Journal of Archaeological Science 52, 549-557. doi:10.1016/j.jas.2014.08.011

Examples

```
## Not run:
data(euroevol)
Ireland <- subset(euroevol,Country=="Ireland")
bins <- binPrep(Ireland$SiteID,Ireland$C14Age,h=200)
x <- calibrate(Ireland$C14Age,Ireland$C14SD)
spd.ireland <- spd(x,bins=bins,runm=200,timeRange=c(8000,4000))
plot(spd.ireland)

## End(Not run)
```

medCal *Computes the median date of calibrated dates*

Description

Function for generating a vector median calibrated dates from a `CalDates` class object.

Usage

```
medCal(x)
```

Arguments

`x`	A `CalDates` class object.

Value

A vector of median dates in cal BP

See Also

`calibrate`, `barCodes`

Examples

```
x <- calibrate(c(3050,2950),c(20,20))
medCal(x)
```

mixCurves *Creates mixed terrestrial/marine calibration curves.*

Description

Function for generating a vector median calibrated dates from a `CalDates` class object.

Usage

```
mixCurves(calCurve = "intcal13", p = 1, resOffsets = 0,
  resErrors = 0)
```

Arguments

`calCurve`	Name of the terrestrial curve, either 'intcal13' or 'shcal13'. Default is 'intcal13'.
`p`	Proportion of terrestrial contribution. Deafult is 1.
`resOffsets`	Offset value for the marine reservoir effect. Default is 0.
`resErrors`	Error of the marine reservoir effect offset. Default is 0.

Details

The function is based on the `mix.calibrationcurves` function of the `clam` package.

Value

A three-column matrix containing calibrated year BP, uncalibrated age bp, and standard deviation. To be used as custom calibration curve for the `calibrate` function.

References

Blaauw, M. and Christen, J.A.. 2011. Flexible paleoclimate age-depth models using an autorgressive gamma process. *Bayesian Analysis*, 6, 457-474. Blaaw, M. 2018. clam: Classical Age-Depth Modelling of Cores from Deposits. R package version 2.3.1. https://CRAN.R-project.org/packacge=clam

See Also

`calibrate`

Examples

```
myCurve <- mixCurves('intcal13',p=0.7,resOffsets=300,resErrors=20)
x <- calibrate(4000,30,calCurves=myCurve)
```

`modelTest` *Monte-Carlo simulation test for SPDs*

Description

Comparison of an observed summed radiocarbon date distribution (aka SPD) with simulated outcomes from a theoretical model.

Usage

```
modelTest(x, errors, nsim, bins = NA, runm = NA, timeRange = NA,
  raw = FALSE, model = c("exponential"), method = c("uncalsample"),
  predgrid = NA, datenormalised = FALSE, spdnormalised = FALSE,
  ncores = 1, fitonly = FALSE, a = 0, b = 0, verbose = TRUE)
```

Arguments

`x`	A `CalDates` object containing calibrated radiocarbon ages
`errors`	A vector of errors corresponding to each radiocarbon age
`nsim`	Number of simulations
`bins`	A vector indicating which bin each radiocarbon date is assigned to.
`runm`	A number indicating the window size of the moving average to smooth both observed and simulated SPDs. If set to `NA` no moving average is applied.Default is `NA`.

timeRange	A vector of length 2 indicating the start and end date of the analysis in cal BP.
raw	A logical variable indicating whether all permuted SPDs should be returned or not. Default is FALSE.
model	A vector indicating the model to be fitted. Currently the acceptable options are 'uniform', 'linear', 'exponential' and 'custom'. Default is 'exponential'.
method	Method for the creation of random dates from the fitted model. Either 'uncalsample' or 'calsample'. Default is 'uncalsample'. See below for details.
predgrid	A data.frame containing calendar years (column calBP) and associated summed probabilities (column PrDens). Required when model is set to 'custom'.
datenormalised	If set to TRUE the total probability mass of each calibrated date will be made to sum to unity (the default in most radiocarbon calibration software). This argument will only have an effect if the dates in x were calibrated without normalisation (via normalised=FALSE in the calibrate function), in which case setting datenormalised=TRUE here will rescale each dates probability mass to sum to unity before aggregating the dates, while setting datenormalised=FALSE will ensure unnormalised dates are used for both observed and simulated SPDs. Default is FALSE.
spdnormalised	A logical variable indicating whether the total probability mass of the SPD is normalised to sum to unity for both observed and simulated data.
ncores	Number of cores used for for parallel execution. Default is 1.
fitonly	A logical variable. If set to TRUE, only the the model fitting is executed and returned. Default is FALSE.
a	Starter value for the exponential fit with the nls function using the formula y ~ exp(a + b * x) where y is the summed probability and x is the date. Default is 0.
b	Starter value for the exponential fit with the nls function using the formula y ~ exp(a + b * x) where y is the summed probability and x is the date. Default is 0.
verbose	A logical variable indicating whether extra information on progress should be reported. Default is TRUE.

Details

The function implements a Monte-Carlo test for comparing a theoretical or fitted statistical model to an observed summed radiocarbon date distribution (aka SPD). A variety of theoretical expectations can be compared to the observed distribution by setting the model argument, for example to fit basic 'uniform' (the mean of the SPD), 'linear' (fitted using the lm function) or model='exponential' models (fitted using the nls function). Models are fitted to the period spanned by timeRange although x can contain dates outside this range to mitigate possible edge effects (see also bracket). Alternatively, it is possible for the user to provide a model of their own by setting model='custom' and then supplying a two-column data.frame to predgrid. The function generates nsim theoretical SPDs from the fitted model via Monte-Carlo simulation, this is then used to define a 95% critical envelope for each calendar year. The observed SPD is then compared against the simulation envelope; local departures from the model are defined as instances where the observed SPD is outside such an envelope, while an estimate of the global significance of

the observed SPD is also computed by comparing the total areas of observed and simulated SPDs that fall outside the simulation envelope. The theoretical SPDs can be generated using two different sampling approaches defined by the parameter `method`. If `method` is set to `'uncalsample'` each date is drawn after the fitted model is backcalibrated as a whole and adjusted for a baseline expectation; if it is set to `'calsample'` samples are drawn from the fitted model in calendar year then individually back calibrated and recalibrated (the approach of Timpson et al. 2014). For each simulation, both approaches produces n samples, with n equal to the number of bins or number of dates (when bins are not defined). Differences between these two approaches are particularly evident at dates coincident with steeper portions of the calibration curve. If more than one type of calibration curve is associated with the observed dates, at each Monte-Carlo iteration, the function randomly assigns each bin to one of the calibration curves with probability based on the proportion of dates within the bin associated to the specific curves. For example, if a bin is composed of four dates and three are calibrated with 'intcal13' the probability of that particular bin being assigned to 'intcal13' is 0.75.

Value

An object of class `SpdModelTest` with the following elements

- `result` A four column data.frame containing the observed probability density (column *PrDens*) and the lower and the upper values of the simulation envelope (columns *lo* and *hi*) for each calendar year column *calBP*
- `sim` A matrix containing the simulation results. Available only when `raw` is set to TRUE
- `pval` A numeric vector containing the p-value of the global significance test.
- `fit` A data.frame containing the probability densities of the fitted model for each calendar year within the time range of analysis
- `fitobject` Fitted model. Not available when `model` is `'custom'`

Note

Windows users might receive a memory allocation error with larger time span of analysis (defined by the parameter `timeRange`). This can be avoided by increasing the memory limit with the `memory.limit` function.

References

Timpson, A., Colledge, S., Crema, E., Edinborough, K., Kerig, T., Manning, K., Thomas, M.G., Shennan, S., (2014). Reconstructing regional population fluctuations in the European Neolithic using radiocarbon dates: a new case-study using an improved method. Journal of Archaeological Science, 52, 549-557. doi:10.1016/j.jas.2014.08.011

Examples

```
## Example with Younger Dryas period Near East, including site bins
## Not run:
data(emedyd)
caldates <- calibrate(x=emedyd$CRA, errors=emedyd$Error, normalised=FALSE, calMatrix=TRUE)
bins <- binPrep(sites=emedyd$SiteName, ages=emedyd$CRA, h=50)
nsim=5 #toy example
```

```
expnull <- modelTest(caldates, errors=emedyd$Error, bins=bins, nsim=nsim, runm=50,
timeRange=c(16000,9000), model="exponential", datenormalised=FALSE)
plot(expnull, xlim=c(16000,9000))
round(expnull$pval,4) #p-value
summary(expnull)

## End(Not run)
```

---

p2pTest *Point to point test of SPD*

Description

Test for evaluating the difference in the summed probability values associated with two points in time.

Usage

```
p2pTest(x, p1 = NA, p2 = NA, interactive = TRUE, plot = FALSE)
```

Arguments

x	result of modelTest with raw=TRUE.
p1	calendar year (in BP) of start point.
p2	calendar year (in BP) of end point.
interactive	if set to TRUE enables an interactive selection of p1 and p2 from a graphical display of the SPD. Disabled when p1 and p2 are defined.
plot	if set to TRUE the function plots the location of p1 and p2 on the SPD. Default is FALSE.

Details

The function compares observed differences in the summed probability values associated with two points in time against a distribution of expected values under the null hypothesis defined with the modelTest function. The two points can be specified manually (assigning BP dates to the arguments p1 and p2) or interactively (clicking on a SPD plot). Note that modelTest should be executed setting the argument raw to TRUE (default is FALSE).

Value

A list with: the BP dates for the two points and the p-value obtained from a two-sided test.

References

Edinborough, K., Porcic, M., Martindale, A., Brown, T.J., Supernant, K., Ames, K.M., (2017). Radiocarbon test for demographic events in written and oral history. PNAS 201713012. doi:10.1073/pnas.1713012114

See Also

modelTest.

Examples

```
## Example with Younger Dryas period Near East, including site bins
## Not run:
data(emedyd)
caldates <- calibrate(x=emedyd$CRA, errors=emedyd$Error, normalised=FALSE, calMatrix=TRUE)
bins <- binPrep(sites=emedyd$SiteName, ages=emedyd$CRA, h=50)
nsim=10 #toy example
expnull <- modelTest(caldates, errors=emedyd$Error, bins=bins, nsim=nsim, runm=50,
timeRange=c(16000,9000), model="exponential", datenormalised=FALSE, raw=TRUE)
p2pTest(x=expnull,p1=13000,p2=12500) #non-interactive mode
p2pTest(x=expnull) #interactive mode

## End(Not run)
```

---

permTest *Random mark permutation test for SPDs*

Description

Global and local significance test for comparing shapes of multiple SPDs using random permutations.

Usage

```
permTest(x, marks, timeRange, nsim, bins = NA, runm = NA,
  datenormalised = FALSE, spdnormalised = FALSE, raw = FALSE,
  verbose = TRUE)
```

Arguments

x	A CalDates class object containing the calibrated radiocarbon dates.
marks	A numerical or character vector containing the marks associated to each radiocarbon date.
timeRange	A vector of length 2 indicating the start and end date of the analysis in cal BP.
nsim	Number of random permutations
bins	A vector indicating which bin each radiocarbon date is assigned to.
runm	A number indicating the window size of the moving average to smooth the SPD. If set to NA no moving average is applied.Default is NA.
datenormalised	If set to TRUE the total probability mass of each calibrated date will be made to sum to unity (the default in most radiocarbon calibration software). This argument will only have an effect if the dates in x were calibrated without normalisation (via normalised=FALSE in the calibrate function), in which case setting

	datenormalised=TRUE here will rescale each dates probability mass to sum to unity before aggregating the dates, while setting datenormalised=FALSE will ensure unnormalised dates are used for both observed and simulated SPDs. Default is FALSE.
spdnormalised	A logical variable indicating whether the total probability mass of the SPD is normalised to sum to unity.
raw	A logical variable indicating whether all permuted SPDs should be returned or not. Default is FALSE.
verbose	A logical variable indicating whether extra information on progress should be reported. Default is TRUE.

Details

The function generates a distribution of expected SPDs by randomly shuffling the marks assigned to each *bin* (see spd for details on binning). The resulting distribution of probabilities for each *mark* (i.e. group of dates) for each calendar year is z-transformed, and a 95% simulation envelope is computed. Local significant departures are defined as instances where the observed SPD (which is also z-transformed) is outside such envelope. A global significance is also computed by comparing the total "area" outside the simulation envelope in the observed and simulated data.

Value

An object of class SpdPermTest with the following elements

- observed A list containing data.frames with the summed probability (column *PrDens* for each calendar year (column *calBP* for each mark/group
- envelope A list containing matrices with the lower and upper bound values of the simulation envelope for each mark/group
- pValueList A list of p-value associated with each mark/group

References

Crema, E.R., Habu, J., Kobayashi, K., Madella, M., (2016). Summed Probability Distribution of 14 C Dates Suggests Regional Divergences in the Population Dynamics of the Jomon Period in Eastern Japan. PLOS ONE 11, e0154809. doi:10.1371/journal.pone.0154809

Examples

```
## compare demographic trajectories in Netherlands and Denmark
## Not run:
data(euroevol)
nld.dnk = subset(euroevol,Country=="Netherlands"|Country=="Denmark")
bins = binPrep(nld.dnk$SiteID,nld.dnk$C14Age,h=200)
dates = calibrate(nld.dnk$C14Age,nld.dnk$C14SD,normalised=FALSE)
res = permTest(dates,marks=as.character(nld.dnk$Country),nsim=1000,
bins=bins,runm=200,timeRange=c(10000,4000))
round(res$pValueList,4) #extract p-values
summary(res)
par(mfrow=c(2,1))
```

```
plot(res,focalm="Netherlands",main="Netherlands")
plot(res,focalm="Denmark",main="Denmark")

## End(Not run)
```

`plot.CalDates` *Plot calibrated dates*

Description

Plot calibrated radiocarbon dates.

Usage

```
## S3 method for class 'CalDates'
plot(x, ind = 1, label = NA, calendar = "BP",
  type = "standard", xlab = NA, ylab = NA, axis4 = TRUE,
  HPD = FALSE, credMass = 0.95, customCalCurve = NA, ...)
```

Arguments

`x`	`CalDates` class object containing calibrated radiocarbon dates.
`ind`	Number indicating the index value of the calibrated radiocarbon date to be displayed. Default is 1.
`label`	(optional) Character vector to be shown on the top-right corner of the display window.
`calendar`	Either `'BP'` or `'BCAD'`. Indicate whether the calibrated date should be displayed in BP or BC/AD. Default is `'BP'`.
`type`	Either `'standard'` or `'auc'`. If set to `'auc'`, displays both the normalised (dashed line) and unnormalised curves. Default is `'standard'`.
`xlab`	(optional) Label for the x axis. If unspecified the default setting will be applied ("Year BP" or "Year BC/AD").
`ylab`	(optional) Label for the y axis. If unspecified the default setting will be applied ("Radiocarbon Age").
`axis4`	Logical value indicating whether an axis of probabilities values should be displayed. Default is TRUE.
`HPD`	Logical value indicating whether intervals of higher posterior density should be displayed. Default is FALSE.
`credMass`	A numerical value indicating the size of the higher posterior density interval. Default is 0.95 (i.e. 95%).
`customCalCurve`	A three column data.frame or matrix that allows you to pass and plot a custom calibration curve if you used one during calibration. You can currently only provide one such custom curve which is used for all dates.
`...`	Additional arguments affecting the plot.

See Also

calibrate

Examples

```
x <- calibrate(x=c(3402,3490,4042),errors=c(20,20,30))
plot(x) #display the first date
plot(x,2) #displays the second date
plot(x,3, calendar="BCAD", HPD=TRUE) #display in BC/AD with higher posterior density interval
```

---

plot.CalGrid *Plot a summed probability distribution (from a CalGrid object)*

Description

Plot a summed radiocarbon probability distribution. This is a basic function for plotting SPDs that have been constructed manually or by calibrating a summed or otherwise irregular CRA grid. In most instances, it is sensible to use `plot.CalSPD` instead.

Usage

```
## S3 method for class 'CalGrid'
plot(x, runm = NA, calendar = "BP",
  fill.p = "grey50", border.p = NA, xlim = NA, ylim = NA,
  cex.lab = 0.75, cex.axis = cex.lab, mar = c(4, 4, 1, 3),
  add = FALSE, ...)
```

Arguments

`x`	A "CalGrid" class object of summed probabilities per calendar year BP.
`runm`	A number indicating the window size of the moving average to smooth the SPD. If set to `NA` no moving average is applied. Default is NA
`calendar`	Either `'BP'` or `'BCAD'`. Indicate whether the calibrated date should be displayed in BP or BC/AD. Default is `'BP'`.
`fill.p`	Fill colour of the polygon depicting the summed probability distribution.
`border.p`	Border colour of the polygon depicting the summed probability distribution.
`xlim`	the x limits of the plot. In BP or in BC/AD depending on the choice of the parameter `calender`. Notice that if BC/AD is selected BC ages should have a minus sign (e.g. `c(-5000,200)` for 5000 BC to 200 AD).
`ylim`	Adjust y axis limits (otherwise sensible default).
`cex.lab`	Size of label text.
`cex.axis`	Size of axis text.
`mar`	Adjust margins around plot.
`add`	Whether or not the new graphic should be added to an existing plot.
`...`	Additional arguments affecting the plot

See Also

spd; plot.CalSPD

Examples

```
data(euroevol)
mycaldates <- calibrate(euroevol[1:10,"C14Age"], euroevol[1:10,"C14SD"], normalised=FALSE)
myspd <- spd(mycaldates, timeRange=c(8000,2000))
plot(myspd) #ordinary plot using \code{plot.CalSPD}
plot(myspd$grid) #working plot using the internal CalGrid object
```

---

plot.CalSPD *Plot a summed probability distribution*

Description

Plot a summed probability distribution (SPD) of radiocarbon dates

Usage

```
## S3 method for class 'CalSPD'
plot(x, runm = NA, calendar = "BP",
  type = "standard", xlim = NA, ylim = NA,
  ylab = "Summed Probability", spdnormalised = FALSE,
  rescale = FALSE, fill.p = "grey75", border.p = NA, xaxt = "s",
  yaxt = "s", add = FALSE, ...)
```

Arguments

x	A CalSPD class object.
runm	A number indicating the window size of the moving average to smooth the SPD. If set to NA no moving average is applied. Default is NA
calendar	Either 'BP' or 'BCAD'. Indicate whether the calibrated date should be displayed in BP or BC/AD. Default is 'BP'.
type	Either 'standard' or 'simple'. The former visualise the SPD as an area graph, while the latter as line chart.
xlim	the x limits of the plot. In BP or in BC/AD depending on the choice of the parameter calender. Notice that if BC/AD is selected BC ages should have a minus sign (e.g. c(-5000,200) for 5000 BC to 200 AD).
ylim	the y limits of the plot.
ylab	(optional) Label for the y axis. If unspecified the default setting will be applied ("Summed Probability")
spdnormalised	A logical variable indicating whether the total probability mass of the SPD is normalised to sum to unity.

rescale	A logical variable indicating whether the SPD should be rescaled to range 0 to 1.
fill.p	Fill colour for the SPD
border.p	Border colour for the SPD
xaxt	Whether the x-axis tick marks should be displayed (xaxt='s', default) or not (xaxt='n').
yaxt	Whether the y-axis tick marks should be displayed (xaxt='s', default) or not (xaxt='n').
add	Whether or not the new graphic should be added to an existing plot.
...	Additional arguments affecting the plot

See Also

spd; plot.CalGrid

Examples

```
## Not run:
data(emedyd)
levant <- emedyd[emedyd$Region=="1"|emedyd$Region=="2",]
bins <- binPrep(levant$SiteName, levant$CRA, h=50)
x <- calibrate(levant$CRA, levant$Error, normalised=FALSE)
spd.levant <- spd(x, bins=bins, timeRange=c(17000,8000))
spd.northernlevant <- spd(x[levant$Region=="2"], bins=bins[levant$Region=="2"],
timeRange=c(17000,8000))
plot(spd.levant, runm=50, xlim=c(16000,9000))
plot(spd.northernlevant, runm=50, add=TRUE, fill.p="black")
legend("topleft", legend=c("All Levant dates","Northern Levant only"),
fill=c("grey75","black"), border=NA)
plot(spd.levant, runm=50, xlim=c(16000,9000), type="simple")
plot(spd.northernlevant, runm=50, col="red", type="simple", add=TRUE)

## End(Not run)
```

---

plot.spatialTest *Plot results of the local spatial permutation test of summed probability distributions.*

Description

Displays local growth rates, p-values, and q-values retrieved from a spatialTest class object.

Usage

```
## S3 method for class 'spatialTest'
plot(x, index = 1, option, breakRange = NA,
  breakLength = 7, rd = 5, baseSize = 0.5, plim = 0.05,
  qlim = 0.05, legend = FALSE, legSize = 1,
  location = "bottomright", ...)
```

Arguments

x	A spatialTest class object
index	A numerical value indicating which transition to display. Ignored when option="rawlegend" or option="testlegend". Default is 1.
option	Indicates what to display. Either "raw" (the local growth rate) or "test" (the test results, i.e. q and p values).
breakRange	A vector of length 2 defining the minimum and maximum values of growth rate to be displayed in the legend. If set to NA its computed from data range (default).
breakLength	A numerical vector defining the number of breaks for growth rates to be displayed in the legend.
rd	Number of decimal places of the growth rate to be displayed in the Legend
baseSize	Numerical value giving the amount by which points should be magnified relative to the default settings in R. Default is 0.5
plim	Threshold value for the p-values. Default is 0.05.
qlim	Threshold value for the q-values. Default is 0.05.
legend	Logical values specifying whether the legend should be displayed or not. Default is FALSE.
legSize	Numerical value giving the amount by which points should be magnified relative to the default settings in R for the Legend. Default is 1.
location	A single keyword from the list "bottomright", "bottom", "bottomleft", "left", "topleft", "top", "topright", "right" and "center" to specify the location of the Legend. Default is "bottomright".
...	Graphical parameters to be passed to methods.

Details

The function displays a distribution map of local growth rates (when option="raw"), q- and p-values (when option="test"), and the associated legends (when option="rawlegend" or option="testlegend").

See Also

SPpermTest

---

plot.spdGG *Plot* spdGG *class objects*

Description

Plot calibrated geometric growth rates.

Usage

```
## S3 method for class 'spdGG'
plot(x, calendar = "BP", ...)
```

Arguments

x	spdGG class object containing geometric growth rates.
calendar	Either 'BP' or 'BCAD'. Indicate whether the calibrated date should be displayed in BP or BC/AD. Default is 'BP'.
...	Additional arguments affecting the plot.

See Also

spd2gg

---

plot.SpdModelTest *Plot result of Monte-Carlo simulation of observed versus modelled SPDs*

Description

The function visualises the observed summed probability distribution of radiocarbon dates along with a simulation envelope for the null model and regions of positive and negative deviation.

Usage

```
## S3 method for class 'SpdModelTest'
plot(x, calendar = "BP", ylim = NA, xlim = NA,
  col.obs = "black", lwd.obs = 0.5, xaxs = "i", yaxs = "i",
  bbty = "f", drawaxes = TRUE, ...)
```

Arguments

x	A SpdModelTest class object generated using the modelTest function.
calendar	Either 'BP' or 'BCAD'. Indicate whether the calibrated date should be displayed in BP or BC/AD. Default is 'BP'.
ylim	the y limits of the plot.
xlim	the x limits of the plot. In BP or in BC/AD depending on the choice of the parameter calender. Notice that if BC/AD is selected BC ages should have a minus sign (e.g. c(-5000,200) for 5000 BC to 200 AD).
col.obs	Line colour for the observed SPD
lwd.obs	Line width for the observed SPD
xaxs	The style of x-axis interval calculation (see par)
yaxs	The style of y-axis interval calculation (see par)

bbty	Display options; one between 'b','n',and 'f'. See details below.
drawaxes	A logical value determining whether the axes should be displayed or not. Default is TRUE.
...	Additional arguments affecting the plot

Details

The argument bbty controls the display options of the Monte-Carlo Test. Default settings (bbty='f') displays the observed SPD (solid black line), the simulation envelope of the fitted model (shaded grey polygon) and regions of significance positive (red semi-transparent rectangle) and negative (blue semi-transparent rectangle) deviation. The option bbty='b' removes the regions of positive/negative deviations, whilst the option bbty='n' displays the simulation envelope on existing plot.

See Also

modelTest

---

plot.SpdPermTest *Plot result of mark permutation test of SPDs*

Description

Visualises the observed SPD along with the simulation envelope generated from permTest, with regions of positive and negative deviations highlighted in red and blue.

Usage

```
## S3 method for class 'SpdPermTest'
plot(x, focalm = "1", calendar = "BP",
  xlim = NA, ylim = NA, col.obs = "black", col.env = rgb(0, 0, 0,
  0.2), lwd.obs = 0.5, xaxs = "i", yaxs = "i", bbty = "f",
  drawaxes = TRUE, ...)
```

Arguments

x	A SpdPermTest class object. Result of random mark permutation test (see permTest)
focalm	Value specifying the name of the focal mark (group) to be plotted.
calendar	Either 'BP' or 'BCAD'. Indicate whether the calibrated date should be displayed in BP or BC/AD. Default is 'BP'.
xlim	the x limits of the plot. In BP or in BC/AD depending on the choice of the parameter calender. Notice that if BC/AD is selected BC ages should have a minus sign (e.g. c(-5000,200) for 5000 BC to 200 AD).
ylim	the y limits of the plot.

col.obs	Line colour for the observed SPD
col.env	Colour for the simulation envelope
lwd.obs	Line width for the observed SPD
xaxs	The style of x-axis interval calculation (see par)
yaxs	The style of y-axis interval calculation (see par)
bbty	Display options; one between 'b','n',and 'f'. See details in plot.SpdModelTest.
drawaxes	A logical value determining whether the axes should be displayed or not. Default is TRUE.
...	Additional arguments affecting the plot

See Also

permTest; plot.SpdModelTest;

---

rcarbon *rcarbon:Calibration and analysis of radiocarbon dates*

Description

The **rcarbon** package handles the calibration and analysis of radiocarbon, often but not exclusively for the purposes of archaeological research. It includes functions not only for basic calibration, uncalibration and plotting of one or more dates, but also a statistical framework for building demographic and related longitudinal inferences from aggregate radiocarbon date lists.

Details

Core functions in the **rcarbon** package can be grouped as follows:

Calibration Functions calibrate and uncalibrate enable the calibration and back-calibration for a variety of curves.

Aggregation Functions spd generates a summed probability distribution (SPD) of radiocarbon dates; binPrep can be used to define clusters of radiocarbon dates associated with the same context/phase

Statistical Test Functions modelTest compares the observed SPD against a variety of theorethical models (most typically an exponential curve) using the Monte-Carlo approach; p2pTest compares observed differences in SPD between two user-specified points in time against differences expected from a theorethical model; permTest compares two or more SPDs and test for the null hypothesis that all sets are derived from the same population; SPpermTest identifies, for defined intervals, locations with significantly higher/lower growth rate in the SPD compared to the pan-regional trend in the data

Note

Up-to-date development version, bug-reports, and further information concerning the **rcarbon** package can be found on GitHub (https://github.com/ahb108/rcarbon). To see the preferable citation of the package, type citation("rcarbon").

Author(s)

The **rcarbon** is developed and maintained by Andrew Bevan and Enrico Crema

References

See individual functions for references.

`reScale` *Rescale a numeric vector to a specified minimum and maximum*

Description

Rescale a numeric vector to a specified minimum and maximum.

Usage

```
reScale(x, type = "simple", to = c(0, 1), na.rm = TRUE)
```

Arguments

`x`	numeric vector to smooth.
`type`	what kind of rescaling to perform. Current options are 'simple' (default) and 'normal' which produces a z-score and 'custom' for which the 'to' argument must be specified.
`to`	numeric vector of length 2 specifying the minimum and maximum value to perform a linear rescale between (default is 0 and 1)
`na.rm`	Set to TRUE,this removes NAs before rescaling.

Value

A numeric vector of rescaled values.

Examples

```
reScale(15:200)
```

runMean *Calculate a running mean from a numeric vector.*

Description

Calculate a running mean from a numeric vector.

Usage

```
runMean(x, n, edge = "NA")
```

Arguments

x	numeric vector to smooth.
n	the size of the window in which to smooth.
edge	How to treat edge cases where a full window is unavailable. Current options are 'NA' to fill with NAs or 'fill' to fill with original values

Value

A numeric vector of smoothed values.

Examples

```
x <- rnorm(1000)
y <- c(1:1000)
plot(y,x, type="l")
lines(runMean(x,50), col="red")
```

smoothGauss *Smooth a numeric vector using a Gaussian window*

Description

Smooth a numeric vector using a Gaussian window

Usage

```
smoothGauss(x, alpha, window = 0.1)
```

Arguments

x	numeric vector of values to smooth.
alpha	numeric value controlling the size of the gaussian smoothing window. Proportional to the standard deviation of the Gaussian smoothing kernel where sd=(N-1)/(2*alpha) with N being the length of the input vector.
window	a fraction between 0 and 1 representing the proportion of the input vector to include in the moving window.

References

Adapted from smth.gaussian

Examples

```
smoothGauss(runif(200),alpha=5)
```

---

spd *Summed probability distributions (SPD) of radiocarbon dates.*

Description

The function generates Summed probability distributions (SPD) of radiocarbon dates, with optional binning routine for controlling inter-site or inter-phase variation in sampling intensity.

Usage

```
spd(x, timeRange, bins = NA, datenormalised = FALSE,
  spdnormalised = FALSE, runm = NA, verbose = TRUE)
```

Arguments

x	A CalDates class object containing the calibrated radiocarbon dates.
timeRange	A vector of length 2 indicating the start and end date of the analysis in cal BP.
bins	A vector containing the bin names associated with each radiocarbon date. If set to NA, binning is not carried out.
datenormalised	Controls for calibrated dates with probability mass outside the timerange of analysis. If set to TRUE the total probability mass within the time-span of analysis is normalised to sum to unity. Should be set to FALSE when the parameter normalised in calibrate is set to FALSE. Default is FALSE.
spdnormalised	A logical variable indicating whether the total probability mass of the SPD is normalised to sum to unity.
runm	A number indicating the window size of the moving average to smooth the SPD. If set to NA no moving average is applied. Default is NA
verbose	A logical variable indicating whether extra information on progress should be reported. Default is TRUE.

Details

The binning routine consists of computing summed probability distribution of all dates associated to a given bin, divided by the number of contributing dates. This controls for any striking differences in sampling intensity, and ensures that each site phase is equally contributing to the final SPD (see Timpson et al 2014 for details). Bins can be generated using the `binPrep`, whilst the sensitivity to parameter choice can be explored with the `binsense` function.

Value

An object of class `CalSPD` with the following elements

- `metadata` A data.frame containing relevant information regarding the parameters used to create the SPD as well as sample size and number of bins
- `grid` A `CalGrid` class object containing the summed probability associated to each calendar year between `timeRange[1]` and `timeRange[2]`

References

Timpson, A., et al, (2014). Reconstructing regional population fluctuations in the European Neolithic using radiocarbon dates: a new case-study using an improved method. Journal of Archaeological Science 52: 549-557. DOI:10.1016/j.jas.2014.08.011

See Also

`calibrate` for calibrating radiocarbon dates; `binPrep` for preparing bins.

---

spd2gg *Compute geometric growth rates from SPDs*

Description

Function for computing the geometric growth rates between abutting user-defined time-blocks.

Usage

```
spd2gg(spd, breaks)
```

Arguments

`spd`	Summed Probability Distribution obtained using the `spd` function.
`breaks`	A vector giving the breakpoints between the time-blocks.

Details

The function computes the growth rate between abutting phases as $(X_t/X_{t+1})^{(1/d)}-1$, where X_t is the summed probability of radiocarbon dates in the block t, and d is the duration of the time-blocks.

Value

An object of class spdGG containing the total summed probability for each time-block and the geometric growth rate between abutting blocks.

Examples

```
## Not run:
data(emedyd)
caldates <- calibrate(x=emedyd$CRA, errors=emedyd$Error, normalised=FALSE, calMatrix=TRUE)
bins <- binPrep(sites=emedyd$SiteName, ages=emedyd$CRA, h=50)
emedyd.spd <- spd(caldates,bins,timeRange=c(16000,9000))
emedyd.gg <- spd2gg(emedyd.spd,breaks=seq(16000,9000,-1000))
plot(emedyd.gg)

## End(Not run)
```

SPpermTest *Spatial Permutation Test of summed probability distributions.*

Description

This function carries out local spatial permutation tests of summed radiocarbon probability distributions in order to detect local deviations in growth rates (Crema et al 2017).

Usage

```
SPpermTest(calDates, timeRange, bins, locations, breaks, spatialweights,
  nsim = 1000, runm = NA, permute = "locations", ncores = 1,
  datenormalised = FALSE, verbose = TRUE, raw = FALSE)
```

Arguments

calDates	A CalDates class object.
timeRange	A vector of length 2 indicating the start and end date of the analysis in cal BP
bins	A vector indicating which bin each radiocarbon date is assigned to. Must have the same length as the number of radiocarbon dates. Can be created using the binPrep) function. Bin names should follow the format "x_y", where x refers to a unique location (e.g. a site) and y is a integer value (e.g. "S023_1", "S023_2","S034_1", etc.).
locations	A SpatialPoints or a SpatialPointsDataFrame class object. Rownames of each point should much the first part of the bin names supplied (e.g. "S023","S034")
breaks	A vector of break points for defining the temporal slices.
spatialweights	A spatialweights class object defining the spatial weights between the locations (cf. spweights)
nsim	The total number of simulations. Default is 1000.

runm	The window size of the moving window average. Must be set to NA if the rates of change are calculated from the raw SPDs.
permute	Indicates whether the permutations should be based on the "bins" or the "locations". Default is "locations".
ncores	Number of cores used for for parallel execution. Default is 1.
datenormalised	A logical variable indicating whether the probability mass of each date within timeRange is equal to 1. Default is FALSE.
verbose	A logical variable indicating whether extra information on progress should be reported. Default is TRUE.
raw	A logical variable indicating whether permuted sets of geometric growth rates for each location should be returned. Default is FALSE.

Details

The function consists of the following seven steps: 1) for each location (e.g. a site) generate a local SPD of radiocarbon dates, weighting the contribution of dates from neighbouring sites using a weight scheme provided by the spatialweights class object; 2) define temporal slices (using breaks as break values), then compute the total probability mass within each slice; 3) compute the rate of change between abutting temporal slices by using the formula: $(SPD_t/SPD_{t+1}^{1/\Delta t} - 1)$; 4) randomise the location of individual bins or the entire sequence of bins associated with a given location and carry out steps 1 to 3; 5) repeat step 4 nsim times and generate, for each location, a distribution of growth rates under the null hypothesis (i.e. spatial independence); 6) compare, for each location, the observed growth rate with the distribution under the null hypothesis and compute the p-values; and 7) compute the false-discovery rate for each location.

Value

A spatialTest class object

References

Crema, E.R., Bevan, A., Shennan, S. (2017). Spatio-temporal approaches to archaeological radiocarbon dates. Journal of Archaeological Science, 87, 1-9.

See Also

permTest for a non-spatial permutation test; plot.spatialTest for plotting; spweights for computing spatial weights; spd2gg for computing geometric growth rates.

Examples

```
## Reproduce Crema et al 2017 ##
## Not run:
data(euroevol) #load data

## Subset only for 8000 to 5000 Cal BP (c7200-4200 C14BP)
edge=800
timeRange=c(8000,5000)
euroevol2=subset(euroevol,C14Age<=c(timeRange[1]-edge)&C14Age>=c(timeRange[2]-edge))
```

```
## define chronological breaks
breaks=seq(8000,5000,-500)

## Create a SpatialPoints class object
library(sp)
sites = unique(data.frame(SiteID=euroevol2$SiteID,
Longitude=euroevol2$Longitude,Latitude=euroevol2$Latitude))
locations=data.frame(Longitude=sites$Longitude,Latitude=sites$Latitude)
rownames(locations)=sites$SiteID
coordinates(locations)<-c("Longitude","Latitude")
proj4string(locations)<- CRS("+proj=longlat +datum=WGS84")

## Compute Distance and Spatial Weights
distSamples=spDists(locations,locations,longlat = TRUE)
spatialweights=spweights(distSamples,h=100) #using a kernal bandwidth of 100km

## Calibration and binning
bins=binPrep(sites=euroevol2$SiteID,ages=euroevol2$C14Age,h=200)
calDates=calibrate(x=euroevol2$C14Age,errors=euroevol2$C14SD,
timeRange=timeRange,normalised=FALSE)

## Main Analysis (over 2 cores; requires doParallel package)
## NOTE: the number of simulations should be ideally larger
## to ensure a better resolution of the p/q-values.
res.locations=SPpermTest(calDates,timeRange=timeRange,bins=bins,locations=locations,
spatialweights=spatialweights,breaks=breaks,ncores=2,nsim=100,
permute="locations",datenormalised=FALSE)

## Plot results
library(rworldmap)
base=getMap(resolution="low") #optionally add base map
#retrieve coordinate limits#
xrange=bbox(res.locations$locations)[1,]
yrange=bbox(res.locations$locations)[2,]

par(mfrow=c(2,2))
par(mar=c(0.1,0.1,0,0.5))
plot(base,col="antiquewhite3",border="antiquewhite3",xlim=xrange,ylim=yrange)
plot(res.locations,index=4,add=TRUE,option="raw",breakRange=c(-0.005,0.005))
plot(res.locations,option="rawlegend",breakRange=c(-0.005,0.005),rd=3)
par(mar=c(0.1,0.1,0,0.5))
plot(base,col="antiquewhite3",border="antiquewhite3",xlim=xrange,ylim=yrange)
plot(res.locations,index=4,add=TRUE,option="test")
plot(res.locations,option="testlegend")

## End(Not run)
```

---

spweights *Compute weights from distance matrix*

Description

Function for computing a matrix of gaussian or fixed weights from distance matrix

Usage

```
spweights(distmat, h = NULL, kernel = "gaussian")
```

Arguments

distmat	a symmetric matrix of inter-site distances (in km).
h	parameter of the Gaussian distance decay function.
kernel	indicates the type of weighting function, either 'fixed' or 'gaussian'. Default is 'gaussian'.

Details

This function generates a weight matrix (required for the SPpermTest) function. When kernel=="fixed", the weight w_{ij} between site i and j is equal to 1 when their interdistance d_{ij} is below h, and equal to 0 when $d_{ij} > h$.When kernel=="gaussian", the weight is calculated with formula exp(-d_ij^2/h^2).

Value

An object of class spatialweights

Examples

```
lon <- c(11.3426,0.1278,0.1218)
lat <- c(44.4949,51.5074,52.2053)
library(sp)
d <- spDists(x=cbind(lon,lat),y=cbind(lon,lat))
spweights(d,h=100)
spweights(d,h=100,kernel="fixed")
```

---

summary.CalDates *Summarise a* CalDates *class object*

Description

Returns summary statistics of calibrated dates.

Usage

```
## S3 method for class 'CalDates'
summary(object, prob = NA, calendar = "BP", ...)
```

Arguments

object	A CalDates class object.
prob	A vector containing probabilities for the higher posterior density interval. Default is c(0.683,0.954), i.e. 1 and 2-Sigma range.
calendar	Whether the summary statistics should be computed in cal BP ("BP") or in BCAD ("BCAD").
...	further arguments passed to or from other methods.

Value

A data.frame class object containing the ID of each date, along with the median date and one and two sigma (or a user specified probability) higher posterior density ranges.

---

summary.SpdModelTest *Summarise a* SpdModelTest *class object*

Description

summary method for class "SpdModelTest"

Usage

```
## S3 method for class 'SpdModelTest'
summary(object, ...)
```

Arguments

object	A SpdModelTest class object produced using the link{modelTest} function.
...	Ignored

Details

The summary function returns metadata (number of radiocarbon dates, bins, and simulations), the p-value of the global signficance test, and the chronological interval of local positive and negative deviations from the simulation envelope.

See Also

modelTest.

summary.SpdPermTest *Summarise a* SpdPermTest *class object*

Description

summary method for class "SpdPermTest"

Usage

```
## S3 method for class 'SpdPermTest'
summary(object, ...)
```

Arguments

object	A SpdPermTest class object produced using the link{permTest} function.
...	Ignored

Details

The summary function returns metadata (number of radiocarbon dates, bins, and simulations), the p-value of the global signficance test, and the chronological interval of local positive and negative deviations from the simulation envelope for each set.

See Also

permTest.

uncalibrate *Uncalibrate (back-calibrate) a calibrated radiocarbon date (or summed probability distribution).*

Description

Function for uncalibrating one or more radiocarbon dates.

Usage

```
uncalibrate(x, ...)

## Default S3 method:
uncalibrate(x, CRAerrors = 0, roundyear = TRUE,
  calCurves = "intcal13", ...)

## S3 method for class 'CalGrid'
uncalibrate(x, calCurves = "intcal13", eps = 1e-05,
  compact = TRUE, verbose = TRUE, ...)
```

Arguments

x	Either a vector of uncalibrated radiocarbon ages or an object of class CalGrid.
...	ignored
CRAerrors	A vector of standard deviations corresponding to each estimated radiocarbon age (ignored if x is a CalGrid object).
roundyear	An optional vector of IDs for each date (ignored if x is a CalGrid object).
calCurves	A string naming a calibration curve already provided with the rcarbon package (currently 'intcal13','intcal13nhpine16','shcal13',"shcal13shkauri16', and 'marine13' are possible) or a custom curve provided as matrix/data.frame in three columns ("CALBP","C14BP","Error"). The default is the 'intcal13' curve and only one curve can currently be specified for all dates.
eps	Cut-off value for density calculation (for CalGrid objects only).
compact	A logical variable indicating whether only uncalibrated ages with non-zero probabilities should be returned (for CalGrid objects only).
verbose	A logical variable indicating whether extra information on progress should be reported (for CalGrid objects only).

Details

This function takes one or more calibrated calendars and looks-up the corresponding uncalibrated age, error of the stated calibration curve at that point. It also provides a randomised estimate of the uncalibrate age based on the curve error (and optionally also a hypothetical measurement error.

Value

A data.frame with specifying the original data, the uncalibrated age without the calibration curve error (ccCRA), the calibration curve error at this point in the curve (ccError), a randomised uncalibrated age (rCRA) given both the stated ccError and any further hypothesised instrumental error provided by the CRAerrors argument (rError).

Examples

```
# Uncalibrate two calendar dates
uncalibrate(c(3050,2950))
```

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