

Package ‘binsmooth’

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Type Package

Title Generate PDFs and CDFs from Binned Data

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Description Provides several methods for generating density functions based on binned data. Methods include step function, recursive subdivision, and optimized spline. Data are assumed to be nonnegative, the top bin is assumed to have no upper bound, but the bin widths need be equal. All PDF smoothing methods maintain the areas specified by the binned data. (Equivalently, all CDF smoothing methods interpolate the points specified by the binned data.) In practice, an estimate for the mean of the distribution should be supplied as an optional argument. Doing so greatly improves the reliability of statistics computed from the smoothed density functions. Includes methods for estimating the Gini coefficient, the Theil index, percentiles, and random deviates from a smoothed distribution. Among the three methods, the optimized spline (splinebins) is recommended for most purposes. The percentile and random-draw methods should be regarded as experimental, and these methods only support splinebins.

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county_bins	<i>ACS County Income Data, 2006-2010</i>
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Description

Binned income data from 3,221 counties in the U.S. and Puerto Rico.

Usage

```
data("county_bins")
```

Format

A data frame with 51536 observations on the following 6 variables.

fips Number identifying the county
households Bin counts
bin_min Left endpoints of bins (US Dollars)
bin_max Right endpoints of bins
county County name
state State name

Source

U.S. Census Bureau, American Community Survey: <https://www.census.gov/programs-surveys/acs/>

See Also

[county_true](#)

Examples

```

data(county_bins)
data(county_true)
binedges <- county_bins$bin_max[county_bins$fips=="6083"]+0.5 # continuity correction
bincounts <- county_bins$households[county_bins$fips=="6083"]
smean <- county_true$mean_true[county_true$fips=="6083"]
plot(splinebins(binedges, bincounts, smean)$splinePDF, 0, 300000,
     n=500, main="Santa Barbara County")
plot(stepbins(binedges, bincounts, smean)$stepPDF, do.points=FALSE, col="red", add=TRUE)

```

county_true

ACS County Income Statistics, 2006-2010

Description

Statistics computed from raw data on 3,221 counties in the U.S. and Puerto Rico.

Usage

```
data("county_true")
```

Format

A data frame with 3221 observations on the following 4 variables.

fips Number identifying the county
mean_true Sample mean
median_true Sample median
gini_true Gini coefficient

Source

U.S. Census Bureau, American Community Survey: <https://www.census.gov/programs-surveys/acs/>

See Also

[county_bins](#)

Examples

```

data(county_bins)
data(county_true)
binedges <- county_bins$bin_max[county_bins$fips=="6083"]+0.5 # continuity correction
bincounts <- county_bins$households[county_bins$fips=="6083"]
smean <- county_true$mean_true[county_true$fips=="6083"]
plot(stepbins(binedges, bincounts, smean)$stepPDF, do.points=FALSE,
     main="Santa Barbara County")

```

gini

*Estimate the Gini coefficient***Description**

Estimates the Gini coefficient from a smoothed distribution.

Usage

```
gini(binFit)
```

Arguments

`binFit` A list as returned by `splinebins`, `stepbins`, or `rsubbins`. (Alternatively, a list containing a PDF of non-negative support, its CDF, and an upper bound for the support of the PDF.)

Details

For distributions of non-negative support, the Gini coefficient can be computed from a cumulative distribution function $F(x)$ by the integral

$$G = 1 - \frac{1}{\mu} \int_0^{\infty} (1 - F(x))^2 dx$$

where μ is the mean of the distribution.

Value

Returns the Gini coefficient G .

Author(s)

David J. Hunter and McKalie Drown

References

Paul T. von Hippel, David J. Hunter, McKalie Drown. *Better Estimates from Binned Income Data: Interpolated CDFs and Mean-Matching*, Sociological Science, November 15, 2017. <https://www.sociologicalscience.com/articles-v4-26-641/>

Examples

```
# 2005 ACS data from Cook County, Illinois
binedges <- c(10000,15000,20000,25000,30000,35000,40000,45000,
             50000,60000,75000,100000,125000,150000,200000,NA)
bincounts <- c(157532,97369,102673,100888,90835,94191,87688,90481,
              79816,153581,195430,240948,155139,94527,92166,103217)
stepfit <- stepbins(binedges, bincounts, 76091)
```

```
splinefit <- splinebins(binedges, bincounts, 76091)
gini(stepfit)
gini(splinefit) # More accurate
```

rsubbins

Recursive subdivision PDF and CDF fitted to binned data

Description

Creates a PDF and CDF based on a set of binned data, using recursive subdivision on a step function.

Usage

```
rsubbins(bEdges, bCounts, m=NULL, eps1 = 0.25, eps2 = 0.75, depth = 3,
         tailShape = c("onebin", "pareto", "exponential"),
         nTail=16, numIterations=20, pIndex=1.160964, tbRatio=0.8)
```

Arguments

bEdges	A vector e_1, e_2, \dots, e_n giving the right endpoints of each bin. The value in e_n is ignored and assumed to be Inf or NA, indicating that the top bin is unbounded. The edges determine n bins on the intervals $e_{i-1} \leq x \leq e_i$, where e_0 is assumed to be 0.
bCounts	A vector c_1, c_2, \dots, c_n giving the counts for each bin (i.e., the number of data elements in each bin). Assumed to be nonnegative.
m	An estimate for the mean of the distribution. If no value is supplied, the mean will be estimated by (temporarily) setting e_n equal to $2e_{n-1}$, and a warning message will be generated.
eps1	Parameter controlling how far the edges of the subdivided bins are shifted. Must be between 0 and 0.5.
eps2	Parameter controlling how wide the middle subdivision of each bin should be. Must be between 0 and 1.
depth	Number of times to subdivide the bins.
tailShape	Must be one of "onebin", "pareto", or "exponential".
nTail	The number of bins to use to form the initial tail, before recursive subdivision. Ignored if tailShape equals "onebin".
numIterations	The number of iterations to optimize the tail to fit the mean. Ignored if tailShape equals "onebin".
pIndex	The Pareto index for the shape of the tail. Defaults to $\ln(5)/\ln(4)$. Ignored unless tailShape equals "pareto".
tbRatio	The decay ratio for the tail bins. Ignored unless tailShape equals "exponential".

Details

First, a step function PDF is created, as described in [stepbins](#). The bins of the resulting PDF are then recursively subdivided and shifted in a manner that preserves the area of the original bins, resulting in a step function with finer bins.

The methods [stepbins](#) and [rsubbins](#) are included in this package mainly for the purpose of comparison. For most use cases, [splinebins](#) will produce more accurate smoothing results.

Value

Returns a list with the following components.

rsubPDF	A stepfun function giving the fitted PDF.
rsubCDF	A piecewise-linear approxfun function giving the CDF.
E	The right-hand endpoint of the support of the PDF.
shrinkFactor	If the supplied estimate for the mean is too small to be fitted with a step function, the bins edges will be scaled by <code>shrinkFactor</code> , which will be chosen less than (and close to) 1.

Author(s)

David J. Hunter and McKalie Drown

References

Paul T. von Hippel, David J. Hunter, McKalie Drown. *Better Estimates from Binned Income Data: Interpolated CDFs and Mean-Matching*, Sociological Science, November 15, 2017. <https://www.sociologicalscience.com/articles-v4-26-641/>

See Also

[stepbins](#)

Examples

```
# 2005 ACS data from Cook County, Illinois
binedges <- c(10000,15000,20000,25000,30000,35000,40000,45000,
             50000,60000,75000,100000,125000,150000,200000,NA)
bincounts <- c(157532,97369,102673,100888,90835,94191,87688,90481,
              79816,153581,195430,240948,155139,94527,92166,103217)
rsb <- rsubbins(binedges, bincounts, 76091, tailShape="pareto")

plot(rsb$rsubPDF, do.points=FALSE)
plot(rsb$rsubCDF, 0, rsb$E)

library(pracma)
integral(rsb$rsubPDF, 0, rsb$E)
integral(function(x){1-rsb$rsubCDF(x)}, 0, rsb$E) #mean is approximated
```

sb_percentiles	<i>Estimate percentiles from splinebins</i>
----------------	---

Description

Estimates percentiles of a smoothed distribution obtained using [splinebins](#).

Usage

```
sb_percentiles(splinebinFit, p = seq(0,100,25))
```

Arguments

`splinebinFit` A list as returned by [splinebins](#).
`p` A vector of percentages in the range $0 \leq p \leq 100$.

Details

The approximate inverse of the CDF calculated by [splinebins](#) is used to approximate percentiles of the smoothed distribution.

Value

A vector of percentiles. Returns NA if an inaccurate fit is detected, as indicated by `fitWarn`.

Author(s)

David J. Hunter and McKalie Drown

References

Paul T. von Hippel, David J. Hunter, McKalie Drown. *Better Estimates from Binned Income Data: Interpolated CDFs and Mean-Matching*, Sociological Science, November 15, 2017. <https://www.sociologicalscience.com/articles-v4-26-641/>

Examples

```
# 2005 ACS data from Cook County, Illinois
binedges <- c(10000,15000,20000,25000,30000,35000,40000,45000,
             50000,60000,75000,100000,125000,150000,200000,NA)
bincounts <- c(157532,97369,102673,100888,90835,94191,87688,90481,
              79816,153581,195430,240948,155139,94527,92166,103217)
splinefit <- splinebins(binedges, bincounts, 76091)
sb_percentiles(splinefit)
sb_percentiles(splinefit, c(27, 32, 93))
```

`sb_sample`*Random sample from splinebins distribution*

Description

Draw a random sample of points from a smoothed distribution obtained using `splinebins`.

Usage

```
sb_sample(splinebinFit, n = 1)
```

Arguments

`splinebinFit` A list as returned by `splinebins`.
`n` A positive integer giving the sample size.

Details

The approximate inverse of the CDF calculated by `splinebins` is used to generate random values of the smoothed distribution.

Value

A vector of random deviates. Returns NA if an inaccurate fit is detected, as indicated by `fitWarn`.

Author(s)

David J. Hunter and McKalie Drown

References

Paul T. von Hippel, David J. Hunter, McKalie Drown. *Better Estimates from Binned Income Data: Interpolated CDFs and Mean-Matching*, Sociological Science, November 15, 2017. <https://www.sociologicalscience.com/articles-v4-26-641/>

Examples

```
# 2005 ACS data from Cook County, Illinois
binedges <- c(10000,15000,20000,25000,30000,35000,40000,45000,
             50000,60000,75000,100000,125000,150000,200000,NA)
bincounts <- c(157532,97369,102673,100888,90835,94191,87688,90481,
              79816,153581,195430,240948,155139,94527,92166,103217)
splinefit <- splinebins(binedges, bincounts, 76091)
sb_sample(splinefit, 5)
hist(sb_sample(splinefit, 3000))
```

simcounty	Simulate data to mimic <code>county_bins</code> and <code>county_true</code>
-----------	--

Description

Samples from a selection of distributions (Gamma, Lognormal, Weibull, Triangle) to simulate income data in the format used in the American Community Survey data (`county_bins` and `county_true`).

Usage

```
simcounty(numCounties, minPop = 1000, maxPop = 100000,  
          bin_minimums = c(0, 10000, 15000, 20000, 25000, 30000, 35000, 40000, 45000,  
                           50000, 60000, 75000, 100000, 125000, 150000, 200000))
```

Arguments

<code>numCounties</code>	The number of counties to simulate data for
<code>minPop</code>	Minimum population to sample (default = 1000)
<code>maxPop</code>	Maximum population to sample (default = 100000)
<code>bin_minimums</code>	Bin edges. Defaults to the edges used in the Census data.

Details

The county names will tell which distributions were sampled to simulate each county.

Value

Returns a list of two data frames:

<code>county_bins</code>	Simulated binned income data
<code>county_true</code>	Statistics computed from the raw data

Author(s)

David J. Hunter and McKalie Drown

References

Paul T. von Hippel, David J. Hunter, McKalie Drown. *Better Estimates from Binned Income Data: Interpolated CDFs and Mean-Matching*, Sociological Science, November 15, 2017. <https://www.sociologicalscience.com/articles-v4-26-641/>

See Also

[county_bins](#), [county_true](#)

Examples

```

l1 <- simcounty(5)
cb <- l1$county_bins
ct <- l1$county_true
sbl <- splinebins(cb$bin_max[cb$fips==103], cb$households[cb$fips==103],
                 ct$mean_true[ct$fips==103])
stl <- stepbins(cb$bin_max[cb$fips==105], cb$households[cb$fips==105],
               ct$mean_true[ct$fips==105])
plot(sbl$splinePDF, 0, 300000, n=500)
plot(stl$stepPDF, do.points=FALSE, main=cb$county[cb$fips==105][1])

## Simulate one county and estimate gini and theil from binned data
l2 <- simcounty(1)
binedges <- l2$county_bins$bin_max + 0.5 # continuity correction
bincounts <- l2$county_bins$households
splinefit <- splinebins(binedges, bincounts, l2$county_true$mean_true)
gini(splinefit)
theil(splinefit)
l2$county_true

```

splinebins

*Optimized spline PDF and CDF fitted to binned data***Description**

Creates a smooth cubic spline CDF and piecewise-quadratic PDF based on a set of binned data (edges and counts).

Usage

```

splinebins(bEdges, bCounts, m = NULL,
           numIterations = 16, monoMethod = c("hyman", "monoH.FC"))

```

Arguments

bEdges	A vector e_1, e_2, \dots, e_n giving the right endpoints of each bin. The value in e_n is ignored and assumed to be Inf or NA, indicating that the top bin is unbounded. The edges determine n bins on the intervals $e_{i-1} \leq x \leq e_i$, where e_0 is assumed to be 0.
bCounts	A vector c_1, c_2, \dots, c_n giving the counts for each bin (i.e., the number of data elements in each bin). Assumed to be nonnegative.
m	An estimate for the mean of the distribution. If no value is supplied, the mean will be estimated by (temporarily) setting e_n equal to $2e_{n-1}$, and a warning message will be generated.
numIterations	The number of iterations performed by a binary search that optimizes the CDF to fit the mean.
monoMethod	The method for constructing a monotone spline. Must be one of "hyman" or "monoH.FC". The former choice tends to integrate faster and produce smoother density functions. See splinefun for more details.

Details

Fits a monotone cubic spline to the points specified by the binned data to produce a smooth cumulative distribution function. The PDF is then obtained by differentiating, so it will be piecewise quadratic and preserve the area of each bin.

Value

Returns a list with the following components.

splinePDF	A piecewise-quadratic function giving the fitted PDF.
splineCDF	A piecewise-cubic function giving the CDF.
E	The right-hand endpoint of the support of the PDF.
shrinkFactor	If the supplied estimate for the mean is too small to be fitted with our method, the bins edges will be scaled by shrinkFactor, which will be chosen less than (and close to) 1.
splineInvCDF	An approximate inverse of splineCDF.
fitWarn	Flag set to TRUE if the fitted median falls in the wrong bin.

Author(s)

David J. Hunter and McKalie Drown

References

Paul T. von Hippel, David J. Hunter, McKalie Drown. *Better Estimates from Binned Income Data: Interpolated CDFs and Mean-Matching*, Sociological Science, November 15, 2017. <https://www.sociologicalscience.com/articles-v4-26-641/>

Examples

```
# 2005 ACS data from Cook County, Illinois
binedges <- c(10000,15000,20000,25000,30000,35000,40000,45000,
             50000,60000,75000,100000,125000,150000,200000,NA)
bincounts <- c(157532,97369,102673,100888,90835,94191,87688,90481,
              79816,153581,195430,240948,155139,94527,92166,103217)
sb <- stepbins(binedges, bincounts, 76091)
splb <- splinebins(binedges, bincounts, 76091)

plot(splb$splinePDF, 0, 300000, n=500)
plot(sb$stepPDF, do.points=FALSE, col="gray", add=TRUE)
# notice that the curve preserves bin area

library(pracma)
integral(splb$splinePDF, 0, splb$E)
integral(function(x){1-splb$splineCDF(x)}, 0, splb$E) # should be the mean
splb <- splinebins(binedges, bincounts, 76091, numIterations=20)
integral(function(x){1-splb$splineCDF(x)}, 0, splb$E) # closer to given mean
```

stats_from_distribution

Estimate various statistics

Description

Estimates the mean, variance, standard deviation, Gini coefficient, and Theil index from a smoothed distribution.

Usage

```
stats_from_distribution(binFit)
```

Arguments

`binFit` A list as returned by [splinebins](#), [stepbins](#), or [rsubbins](#). (Alternatively, a list containing a PDF of non-negative support, its CDF, and an upper bound for the support of the PDF.)

Details

The mean and variance are calculated from the CDF. For details on the other statistics, see [gini](#) and [theil](#).

Value

A vector of five statistics.

Author(s)

David J. Hunter and McKalie Drown

References

Paul T. von Hippel, David J. Hunter, McKalie Drown. *Better Estimates from Binned Income Data: Interpolated CDFs and Mean-Matching*, Sociological Science, November 15, 2017. <https://www.sociologicalscience.com/articles-v4-26-641/>

Examples

```
# 2005 ACS data from Cook County, Illinois
binedges <- c(10000,15000,20000,25000,30000,35000,40000,45000,
             50000,60000,75000,100000,125000,150000,200000,NA)
bincounts <- c(157532,97369,102673,100888,90835,94191,87688,90481,
              79816,153581,195430,240948,155139,94527,92166,103217)
stepfit <- stepbins(binedges, bincounts, 76091)
splinefit <- splinebins(binedges, bincounts, 76091)
stats_from_distribution(stepfit)
stats_from_distribution(splinefit) # More accurate
```

stepbins

Step function PDF and CDF fitted to binned data

Description

Creates a step function PDF and CDF based on a set of binned data (edges and counts).

Usage

```
stepbins(bEdges, bCounts, m = NULL,
         tailShape = c("onebin", "pareto", "exponential"),
         nTail = 16, numIterations = 20, pIndex = 1.160964, tbRatio = 0.8)
```

Arguments

bEdges	A vector e_1, e_2, \dots, e_n giving the right endpoints of each bin. The value in e_n is ignored and assumed to be Inf or NA, indicating that the top bin is unbounded. The edges determine n bins on the intervals $e_{i-1} \leq x \leq e_i$, where e_0 is assumed to be 0.
bCounts	A vector c_1, c_2, \dots, c_n giving the counts for each bin (i.e., the number of data elements in each bin). Assumed to be nonnegative.
m	An estimate for the mean of the distribution. If no value is supplied, the mean will be estimated by (temporarily) setting e_n equal to $2e_{n-1}$, and a warning message will be generated.
tailShape	Must be one of "onebin", "pareto", or "exponential".
nTail	The number of bins to use to form the tail. Ignored if tailShape equals "onebin".
numIterations	The number of iterations to optimize the tail to fit the mean. Ignored if tailShape equals "onebin".
pIndex	The Pareto index for the shape of the tail. Defaults to $\ln(5)/\ln(4)$. Ignored unless tailShape equals "pareto".
tbRatio	The decay ratio for the tail bins. Ignored unless tailShape equals "exponential".

Details

We assume that the left endpoint of the first bin is 0 and that the top bin is unbounded. Options exist to replace the top bin with a single bin or a sequence of bins in the shape of a Pareto or exponential tail. The density functions will fit a supplied estimate for the population mean, if supplied.

The methods [stepbins](#) and [rsubbins](#) are included in this package mainly for the purpose of comparison. For most use cases, [splinebins](#) will produce more accurate smoothing results.

Value

Returns a list with the following components.

stepPDF	A <code>stepfun</code> function giving the fitted PDF.
stepCDF	A piecewise-linear <code>approxfun</code> function giving the CDF.
E	The right-hand endpoint of the support of the PDF.
shrinkFactor	If the supplied estimate for the mean is too small to be fitted with a step function, the bins edges will be scaled by <code>shrinkFactor</code> , which will be chosen less than (and close to) 1.

Author(s)

David J. Hunter and McKalie Drown

References

Paul T. von Hippel, David J. Hunter, McKalie Drown. *Better Estimates from Binned Income Data: Interpolated CDFs and Mean-Matching*, Sociological Science, November 15, 2017. <https://www.sociologicalscience.com/articles-v4-26-641/>

Examples

```
# 2005 ACS data from Cook County, Illinois
binedges <- c(10000,15000,20000,25000,30000,35000,40000,45000,
             50000,60000,75000,100000,125000,150000,200000,NA)
bincounts <- c(157532,97369,102673,100888,90835,94191,87688,90481,
              79816,153581,195430,240948,155139,94527,92166,103217)
sb <- stepbins(binedges, bincounts, 76091)
sbpt <- stepbins(binedges, bincounts, 76091, tailShape="pareto")

plot(sb$stepPDF)
plot(sbpt$stepPDF, do.points=FALSE)
plot(sb$stepCDF, 0, sb$E+100000)

library(pracma)
integral(sb$stepPDF, 0, sb$E) # should be approximately 1
integral(function(x){1-sb$stepCDF(x)}, 0, sb$E) # should be the mean
```

theil

Estimate the Theil index

Description

Estimates the Theil index from a smoothed distribution.

Usage

```
theil(binFit)
```

Arguments

`binFit` A list as returned by `splinebins`, `stepbins`, or `rsubbins`. (Alternatively, a list containing a PDF of non-negative support, its CDF, and an upper bound for the support of the PDF.)

Details

For distributions of non-negative support, the Theil index can be computed from a probability density function $f(x)$ by the integral

$$T = \int_0^{\infty} f(x) \frac{x}{\mu} \ln \left(\frac{x}{\mu} \right) dx$$

where μ is the mean of the distribution.

Value

Returns the Theil index T .

Author(s)

David J. Hunter and McKalie Drown

References

Paul T. von Hippel, David J. Hunter, McKalie Drown. *Better Estimates from Binned Income Data: Interpolated CDFs and Mean-Matching*, Sociological Science, November 15, 2017. <https://www.sociologicalscience.com/articles-v4-26-641/>

Examples

```
# 2005 ACS data from Cook County, Illinois
binedges <- c(10000,15000,20000,25000,30000,35000,40000,45000,
             50000,60000,75000,100000,125000,150000,200000,NA)
bincounts <- c(157532,97369,102673,100888,90835,94191,87688,90481,
              79816,153581,195430,240948,155139,94527,92166,103217)
stepfit <- stepbins(binedges, bincounts, 76091)
splinefit <- splinebins(binedges, bincounts, 76091)
theil(stepfit)
theil(splinefit) # More accurate
```

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