Package ‘bs’

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Type Package

Title Package for the Birnbaum-Saunders distribution

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Author Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

Maintainer Hugo Hernández <hugo.hernandez@msn.com>

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Description A collection of utilities for the Birnbaum-Saunders distribution (BSD).

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`bs-package` *Package for the Birnbaum-Saunders distribution.*

Description

A collection of utilities for the Birnbaum-Saunders distribution (BSD).

Details

Package:	bs
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Birnbaum and Saunders (1969) proposed a two-parameter failure time distribution for fatigue failure caused under cyclic loading. It was also assumed that the failure is due to the development and growth of a dominant crack.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

Maintainer: Hugo Hernández <hugo.hernandez@msn.com>.

References

Birnbaum, Z. W. and Saunders, S. C. (1969). A new family of life distributions. J. Appl. Probab. 6(2): 637-652.

Leiva, V., Hernández, H., and Riquelme, M. (2006). A New Package for the Birnbaum-Saunders Distribution. Rnews, 6/4, 35-40. (http://www.r-project.org)

Examples

```
## Load package
library(bs)

## density for the Birnbaum-Saunders distribution
## with parameters alpha=0.5 y beta=1.0 in x=3.
dbs(3,alpha=0.5,beta=1.0,log=FALSE)
```

`aicbs` *Akaike information criterium (AIC) for a sample of the BSD*

Description

The function `aicbs()` gives the AIC value assuming an BSD with parameters alpha and beta. `aicbs()` is based on the invariance property of the MLE.

Usage

```
aicbs(x)
```

Arguments

`x`	Vector of observations.

Details

The SIC is a selection model criterion based on information loss. According to this criterion, it is possible to choose a hypothetic model that better describe the data set considering the smaller SIC value. The SIC is defined as $SIC = -l(\theta)/n + p\log(n)/(2n)$, where $l(\theta)$ is the log-likelihood function associated with the model, n is the sample size, and p is the number of involved parameters; for more details see Spieglhaiter, Best, Carlin and van der Linde (2002). AIC is an alternative information criterium.

Value

The function `aicbs()` gives the AIC value.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Schwarz, S. (1978). Estimating the dimension of the model. Annals of Statistics, 6, 461-464.

Spieglhaiter, D. J., Best, N. G., Carlin, B. P. and van der Linde, A. (2002). Bayesian measures of complexity and fit. Journal of the Royal Statistical Society Series B 64, 1-34.

Leiva, V., Hernández, H., and Riquelme, M. (2006). A New Package for the Birnbaum-Saunders Distribution. Rnews, 6/4, 35-40. (http://www.r-project.org)

Examples

```
## Load data sets
data(psi31)

## Calculus of AIC for psi31
aicbs(psi31)
```

`bearings` *Fatigue lifetime data*

Description

Several data sets related to the BSD are available in the bs package, which have been taken from the literature on this topic.

Usage

```
data(bearings)
```

Format

A vector containing 10 observations.

Details

McCool (1974) gives data related to the fatigue life in hours of 10 bearings of a certain type.

References

McCool, J. I. (1974). Inferential techniques for Weibull populations. Aerospace Research Laboratories Report ARL TR74-0180, Wright-Patterson Air Force Base, Dayton, OH.

Examples

```
## Load data sets
data(bearings)
## Histogram for bearings
hist(bearings)
```

---

beta1bs *The square of skewness coefficient for the BSD*

Description

Estimation of the square of skewness coefficient (SSC) for the Birnbaum-Saunders distribution.

Usage

```
beta1bs(x)
```

Arguments

`x`	Vector of observations.

Details

Methods of goodness-of-fit based on moments ($\beta_1 - \beta_2$ chart).

Value

The function `beta1bs()` gives the SSC value.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Leiva, V., Hernández, H., and Riquelme, M. (2006). A New Package for the Birnbaum-Saunders Distribution. Rnews, 6/4, 35-40. (http://www.r-project.org)

Examples

```
## beta1-beta2 chart
## Example: 12 BSD samples have been simulated by using 'rbs()' for the values
## alfa = 0.2,0.4,0.5,0.6,0.8,1.0,1.2,1.4,1.8,2.0,2.2,2.4
## beta = 1.0
sample1<-rbs(30,0.2,1.0)
sample2<-rbs(30,0.4,1.0)
sample3<-rbs(30,0.6,1.0)
sample4<-rbs(30,0.8,1.0)
```

```
sample5<-rbs(30,1.0,1.0)
sample6<-rbs(30,1.2,1.0)
sample7<-rbs(30,1.4,1.0)
sample8<-rbs(30,1.6,1.0)
sample9<-rbs(30,1.8,1.0)
sample10<-rbs(30,2.0,1.0)
sample11<-rbs(30,2.2,1.0)
sample12<-rbs(30,2.4,1.0)

x1<-c(beta1bs(sample1),beta2bs(sample1))
x2<-c(beta1bs(sample2),beta2bs(sample2))
x3<-c(beta1bs(sample3),beta2bs(sample3))
x4<-c(beta1bs(sample4),beta2bs(sample4))
x5<-c(beta1bs(sample5),beta2bs(sample5))
x6<-c(beta1bs(sample6),beta2bs(sample6))
x7<-c(beta1bs(sample7),beta2bs(sample7))
x8<-c(beta1bs(sample8),beta2bs(sample8))
x9<-c(beta1bs(sample9),beta2bs(sample9))
x10<-c(beta1bs(sample10),beta2bs(sample10))
x11<-c(beta1bs(sample11),beta2bs(sample11))
x12<-c(beta1bs(sample12),beta2bs(sample12))
x<-c(x1[1],x2[1],x3[1],x4[1],x5[1],x6[1],x7[1],x8[1],x9[1],x10[1],x11[1],x12[1])
y<-c(x1[2],x2[2],x3[2],x4[2],x5[2],x6[2],x7[2],x8[2],x9[2],x10[2],x11[2],x12[2])

## Generate the graph
plot(x,y,xlab=expression(beta[1]),ylab=expression(beta[2]),col=4,lwd=2.0)
fitbetabs(0.2,2)
fitbetabs(2.4,3)
```

`beta2bs` *The coefficient of kurtosis of the BSD*

Description

Estimation of the coefficient of kurtosis (CK) for the Birnbaum-Saunders distribution.

Usage

```
beta2bs(x)
```

Arguments

`x`	Vector of observations.

Details

Methods of goodness-of-fit based on moments ($\beta_1 - \beta_2$ chart).

Value

The function `beta2bs()` gives the CK value.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Leiva, V., Hernández, H., and Riquelme, M. (2006). A New Package for the Birnbaum-Saunders Distribution. Rnews, 6/4, 35-40. (http://www.r-project.org)

Examples

```
## beta1-beta2 chart
## Example: 12 BSD samples have been simulated by using 'rbs()' for the values
## alfa = 0.2,0.4,0.5,0.6,0.8,1.0,1.2,1.4,1.8,2.0,2.2,2.4
## beta = 1.0
sample1<-rbs(30,0.2,1.0)
sample2<-rbs(30,0.4,1.0)
sample3<-rbs(30,0.6,1.0)
sample4<-rbs(30,0.8,1.0)
sample5<-rbs(30,1.0,1.0)
sample6<-rbs(30,1.2,1.0)
sample7<-rbs(30,1.4,1.0)
sample8<-rbs(30,1.6,1.0)
sample9<-rbs(30,1.8,1.0)
sample10<-rbs(30,2.0,1.0)
sample11<-rbs(30,2.2,1.0)
sample12<-rbs(30,2.4,1.0)

x1<-c(beta1bs(sample1),beta2bs(sample1))
x2<-c(beta1bs(sample2),beta2bs(sample2))
x3<-c(beta1bs(sample3),beta2bs(sample3))
x4<-c(beta1bs(sample4),beta2bs(sample4))
x5<-c(beta1bs(sample5),beta2bs(sample5))
x6<-c(beta1bs(sample6),beta2bs(sample6))
x7<-c(beta1bs(sample7),beta2bs(sample7))
x8<-c(beta1bs(sample8),beta2bs(sample8))
x9<-c(beta1bs(sample9),beta2bs(sample9))
x10<-c(beta1bs(sample10),beta2bs(sample10))
x11<-c(beta1bs(sample11),beta2bs(sample11))
x12<-c(beta1bs(sample12),beta2bs(sample12))
x<-c(x1[1],x2[1],x3[1],x4[1],x5[1],x6[1],x7[1],x8[1],x9[1],x10[1],x11[1],x12[1])
y<-c(x1[2],x2[2],x3[2],x4[2],x5[2],x6[2],x7[2],x8[2],x9[2],x10[2],x11[2],x12[2])

## Generate the graph
plot(x,y,xlab=expression(beta[1]),ylab=expression(beta[2]),col=4,lwd=2.0)
fitbetabs(0.2,2)
fitbetabs(2.4,3)
```

biaxial — *Brown and Miller's biaxial fatigue data*

Description

Several data sets related to the BSD are available in the bs package, which have been taken from the literature on this topic.

Usage

```
data(biaxial)
```

Format

A vector containing 46 observations.

Details

Rieck and Nedelman (1991) reported a data set from Brown and Miller (1978). These data represent results of fatigue tests on 1% Cr-Mo-V steel. Cylindrical specimens were subjected to combined torsional and axial loads over constant-amplitude cycles until failure.

References

Rieck, J. R. and Nedelman, J. (1991). A Log-Linear Model for the Birnbaum-Saunders Distribution. Technometrics. 33, 51-60.

Brown, M. W. and Miller, K. J. (1978). Biaxial Fatigue Data. Report CEMR1/78. University of Sheffield, Dept. of Mechanical Engineering.

Examples

```
## Load data sets
data(biaxial)
## Histogram for biaxial
hist(biaxial)
```

crfbs — *Conditional reliability function (crf) for the BSD*

Description

Conditional reliability function for the BSD with shape parameter alpha and scale parameter beta.

Usage

```
crfbs(t, x = 0, alpha = 1, beta = 1)
```

Arguments

`t`	Vector of quantiles.
`x`	Age component in used.
`alpha`	Shape parameter.
`beta`	Scale parameter.

Details

One of the useful indicators in lifetime analysis is the hazard function (h.f.), which is defined by

$$h_T(t) = \frac{f_T(t)}{1 - F_T(t)},\, t > 0,\, 0 < F_T(t) < 1,$$

where $f_T(\cdot)$ and $F_T(\cdot)$ are the pdf and cdf, respectively; see e.g. Johnson, Kotz, and Balakrishnan (1994, p. 640). The behavior of $h_T(t)$ allows one to characterize the aging of the units. For example, if the failure rate is increasing (IFR class), then the units age with time. If $h_T(t)$ is decreasing (DFR class), then the units improve in performance with time. Finally, if $h_T(t)$ is constant, then the lifetime distribution is necessarily exponential.

Another aging indicators are the following:

The failure rate average (FRA) of T is given by

$$FRA(t) = \frac{H_T(t)}{t} = \frac{\int_0^t h_T(t)\, dt}{t},\, t > 0,$$

where $H_T(t)$ is the cumulative hazard function. An analysis for FRA(t) on t permits to obtain the IFRA and DFRA classes.

The survival function (s.f.) and the conditional survival of T are defined by

$$R_T(t) = 1 - F_T(t) \quad \text{and} \quad R_T(t|x) = \frac{R_T(t + x)}{R_T(x)},\, t > 0,\, x > 0,\, R_T(\cdot) > 0,$$

respectively, where $F_T(\cdot)$ is the cdf of T. Similarly to $h_T(t)$ and $FRA(t)$, the distribution of T belongs to the new better than used (NBU), exponential, or new worse than used (NWU) classes, when $R_T(t|x) < R_T(t)$, $R_T(t|x) = R_T(t)$, or $R_T(t|x) > R_T(t)$, respectively.

Value

Conditional reliability function for the BSD.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Hoyland, A. and Rausand, M. (1994). System Reliability Theory. John Wiley and Sons. N. Y.

Examples

```
## Reliability indicators:

## Reliability function
rfbs(3,0.5,1.0)

## Conditional reliability function
crfbs(3,0,0.5,1.0)

## Conditional reliability function (age component=0)
crfbs(3,x=0,0.5,1.0)

## Conditional reliability function (age component=0)
crfbs(3,x=2,0.5,1.0)

## failure rate
frbs(3,0.5,1.0)

## failure rate average
frabs(3,0.5,1.0)
```

`dbs` *Probability density function (pdf) of the Birnbaum-Saunders distribution*

Description

Probability density function for the BSD with shape parameter alpha and scale parameter beta.

Usage

```
dbs(x, alpha = 1, beta = 1, log = FALSE)
```

Arguments

`x`	Vector of quantiles.
`alpha`	Shape parameter.
`beta`	Scale parameter.
`log`	Logical; if TRUE, probabilities p are given as log(p).

Details

Birnbaum and Saunders (1969) proposed the two-parameter Birnbaum-Saunders distribution with density

$$f_T(t) = \frac{1}{\sqrt{2\pi}} \exp\left[-\frac{1}{2\alpha^2}\left(\frac{t}{\beta} + \frac{\beta}{t} - 2\right)\right] \frac{t^{-\frac{3}{2}}(t+\beta)}{2\alpha\sqrt{\beta}};\ t > 0, \alpha > 0, \beta > 0,$$

as a failure time distribution for fatigue failure caused under cyclic loading. The parameters alpha and beta are the shape and the scale parameters, respectively. In their derivation, it was assumed that the failure is due to the development and growth of a dominant crack.

Value

`dbs()` gives the pdf of an BSD.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Birnbaum, Z. W. and Saunders, S. C. (1969). A new family of life distributions. J. Appl. Probab. 6(2): 637-652.

Examples

```
## Load package
library(bs)

## density for the Birnbaum-Saunders distribution
## with parameters alpha=0.5 y beta=1.0 in x=3.
dbs(3,alpha=0.5,beta=1.0,log=FALSE)
```

`delta2bs` *The square of coefficient of variation of the BSD*

Description

Estimation of the square of coefficient of variation (CV) for the Birnbaum-Saunders distribution.

Usage

```
delta2bs(x)
```

Arguments

`x`	Vector of observations.

Details

Methods of goodness-of-fit based on moments ($\delta_2 - \delta_3$ chart).

Value

The function `delta2bs()` gives the CV value.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Leiva, V., Hernández, H. and Riquelme, M. (2006). A New Package for the Birnbaum-Saunders Distribution. Rnews, 6/4, 35-40. (http://www.r-project.org)

Examples

```
## delta2-delta3 chart
## Example: 12 BSD samples have been simulated by using 'rbs()' for the values
## alfa = 0.2,0.4,0.5,0.6,0.8,1.0,1.2,1.4,1.8,2.0,2.2,2.4
## beta = 1.0
sample1<-rbs(30,0.2,1.0)
sample2<-rbs(30,0.4,1.0)
sample3<-rbs(30,0.6,1.0)
sample4<-rbs(30,0.8,1.0)
sample5<-rbs(30,1.0,1.0)
sample6<-rbs(30,1.2,1.0)
sample7<-rbs(30,1.4,1.0)
sample8<-rbs(30,1.6,1.0)
sample9<-rbs(30,1.8,1.0)
sample10<-rbs(30,2.0,1.0)
sample11<-rbs(30,2.2,1.0)
sample12<-rbs(30,2.4,1.0)

x1<-c(delta2bs(sample1),delta3bs(sample1))
x2<-c(delta2bs(sample2),delta3bs(sample2))
x3<-c(delta2bs(sample3),delta3bs(sample3))
x4<-c(delta2bs(sample4),delta3bs(sample4))
x5<-c(delta2bs(sample5),delta3bs(sample5))
x6<-c(delta2bs(sample6),delta3bs(sample6))
x7<-c(delta2bs(sample7),delta3bs(sample7))
x8<-c(delta2bs(sample8),delta3bs(sample8))
x9<-c(delta2bs(sample9),delta3bs(sample9))
x10<-c(delta2bs(sample10),delta3bs(sample10))
x11<-c(delta2bs(sample11),delta3bs(sample11))
x12<-c(delta2bs(sample12),delta3bs(sample12))
x<-c(x1[1],x2[1],x3[1],x4[1],x5[1],x6[1],x7[1],x8[1],x9[1],x10[1],x11[1],x12[1])
y<-c(x1[2],x2[2],x3[2],x4[2],x5[2],x6[2],x7[2],x8[2],x9[2],x10[2],x11[2],x12[2])

## Genera el gráfico
plot(x,y,xlab=expression(delta[2]),ylab=expression(delta[3]),col=4,lwd=2.0)
fitdeltabs(0.2,2)
fitdeltabs(2.4,3)
```

delta3bs — *The coefficient of skewness for the BSD*

Description

Estimation of the coefficient of skewness (CS) for the Birnbaum-Saunders distribution.

Usage

```
delta3bs(x)
```

Arguments

`x`	Vector of observations.

Details

Methods of goodness-of-fit based on moments ($\delta_2 - \delta_3$ chart).

Value

The function `delta3bs()` gives the CS value.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Leiva, V., Hernández, H., and Riquelme, M. (2006). A New Package for the Birnbaum-Saunders Distribution. Rnews, 6/4, 35-40. (http://www.r-project.org)

Examples

```
## delta2-delta3 chart
## Example: 12 BSD samples have been simulated by using 'rbs()' for the values
## alfa = 0.2,0.4,0.5,0.6,0.8,1.0,1.2,1.4,1.8,2.0,2.2,2.4
## beta = 1.0
sample1<-rbs(30,0.2,1.0)
sample2<-rbs(30,0.4,1.0)
sample3<-rbs(30,0.6,1.0)
sample4<-rbs(30,0.8,1.0)
sample5<-rbs(30,1.0,1.0)
sample6<-rbs(30,1.2,1.0)
sample7<-rbs(30,1.4,1.0)
sample8<-rbs(30,1.6,1.0)
sample9<-rbs(30,1.8,1.0)
sample10<-rbs(30,2.0,1.0)
```

```
sample11<-rbs(30,2.2,1.0)
sample12<-rbs(30,2.4,1.0)

x1<-c(delta2bs(sample1),delta3bs(sample1))
x2<-c(delta2bs(sample2),delta3bs(sample2))
x3<-c(delta2bs(sample3),delta3bs(sample3))
x4<-c(delta2bs(sample4),delta3bs(sample4))
x5<-c(delta2bs(sample5),delta3bs(sample5))
x6<-c(delta2bs(sample6),delta3bs(sample6))
x7<-c(delta2bs(sample7),delta3bs(sample7))
x8<-c(delta2bs(sample8),delta3bs(sample8))
x9<-c(delta2bs(sample9),delta3bs(sample9))
x10<-c(delta2bs(sample10),delta3bs(sample10))
x11<-c(delta2bs(sample11),delta3bs(sample11))
x12<-c(delta2bs(sample12),delta3bs(sample12))
x<-c(x1[1],x2[1],x3[1],x4[1],x5[1],x6[1],x7[1],x8[1],x9[1],x10[1],x11[1],x12[1])
y<-c(x1[2],x2[2],x3[2],x4[2],x5[2],x6[2],x7[2],x8[2],x9[2],x10[2],x11[2],x12[2])

## Genera el gráfico
plot(x,y,xlab=expression(delta[2]),ylab=expression(delta[3]),col=4,lwd=2.0)
fitdeltabs(0.2,2)
fitdeltabs(2.4,3)
```

`est1bs` *Maximum likelihood estimation (MLE) of the Birnbaum-Saunders distribution*

Description

The function `est1bs()` estimates the parameters alpha and beta of the BSD from a sample of observations by using the likelihood method (MLE) and the mean-mean estimator; see Birnbaum and Saunders (1969).

Usage

```
est1bs(x)
```

Arguments

`x`	Vector of observations.

Value

The function `est1bs()` returns a list with four elements:

`alpha`	Estimation of alpha by using MLE method.
`beta`	Estimation of beta by using MLE method.
`beta.start`	Estimation of mean-mean estimator.
`iterations`	Number of iterations of the process.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Birnbaum, Z. W. and Saunders, S. C. (1969). Estimation for a family of life distributions with applications to fatigue. J. Appl. Probab. 6(2): 328-347.

Leiva, V., Hernández, H., and Riquelme, M. (2006). A New Package for the Birnbaum-Saunders Distribution. Rnews, 6/4, 35-40. (http://www.r-project.org)

Examples

```
## Load package
library(bs)

## Load data sets
data(psi31)

## Examples for parameters estimation
est1bs(psi31)
est2bs(psi31)
est3bs(psi31)
```

`est2bs` *Graphical method estimation (GME) of the Birnbaum-Saunders distribution*

Description

The function `est2bs()` estimates the parameters alpha and beta of the BSD from a sample of observations by using the graphical method (GME) developed by Chang and Tang (1994). In addition, optionally, the function `est2bs()` produces a GME plot for the BSD based on the least squares method.

Usage

```
est2bs(x, plot = "FALSE")
```

Arguments

`x`	Vector of observations.
`plot`	Logical; if TRUE, the GME plot is provided.

Value

The function `est2bs()` returns a list with three elements:

`alpha`	Estimation of alpha by using GME method.
`beta`	Estimation of beta by using GME method.
`r.squared`	Coefficient of determination of least squares for GME plot.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Birnbaum, Z.W. and Saunders, S.C. (1969). Estimation for a family of life distributions with applications to fatigue. J. Appl. Probab. 6(2): 328-347.

Leiva, V., Hernández, H., and Riquelme, M. (2006). A New Package for the Birnbaum-Saunders Distribution. Rnews, 6/4, 35-40. (http://www.r-project.org)

D.S. Chang and L.C. Tang (1994). Graphical analysis for Birnbaum-Saunders distribution. Microelectronics and Reliability, 34(1): 17-22.

Examples

```
## Load package
library(bs)

## Load data sets
data(psi31)

## Examples for parameters estimation
est1bs(psi31)
est2bs(psi31)
est3bs(psi31)
```

`est3bs` *Modified moment estimation (MME) of the Birnbaum-Saunders distribution*

Description

The function `est3bs()` estimates the parameters alpha and beta of the BSD from a sample of observations by using the modified moment method (MLE); see Ng, Kundub and Balakrishnan (2006).

Usage

```
est3bs(x)
```

Arguments

`x`	Vector of observations.

Value

The function `est3bs()` returns a list with two elements:

`alpha`	Estimation of alpha by using MME method.
`beta`	Estimation of beta by using MME method.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Birnbaum, Z. W. and Saunders, S. C. (1969). Estimation for a family of life distributions with applications to fatigue. J. Appl. Probab. 6(2): 328-347.

Ng, H. K., Kundub, D., Balakrishnan, N. (2006). Point and interval estimation for the two-parameter Birnbaum-Saunders distribution based on Type-II censored samples. Computational Statistics and Data Analysis 50:3222-3242.

Leiva, V., Hernández, H., and Riquelme, M. (2006). A New Package for the Birnbaum-Saunders Distribution. Rnews, 6/4, 35-40. (http://www.r-project.org)

Examples

```
## Load package
library(bs)

## Load data sets
data(psi31)

## Examples for parameters estimation
est1bs(psi31)
est2bs(psi31)
est3bs(psi31)
```

`fitbetabs` *beta1-beta2 line fit*

Description

The functions `fitbetabs()` and `fitdeltabs()` allow to one to add a fitting line based on an specified value of alpha for these charts.

Usage

```
fitbetabs(alpha = 1, col = 2)
```

Arguments

`alpha`	Shape parameter of Birnbaum-Saunders distribution.
`col`	Color of line.

Details

Methods of goodness-of-fit based on moments ($\beta_1 - \beta_2$ chart).

Value

Add a line to delta2-delta3 chart.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Leiva, V., Hernández, H., and Riquelme, M. (2006). A New Package for the Birnbaum-Saunders Distribution. Rnews, 6/4, 35-40. (http://www.r-project.org)

Examples

```
## beta1-beta2 chart
## Example: 12 BSD samples have been simulated by using 'rbs()' for the values
## alfa = 0.2,0.4,0.5,0.6,0.8,1.0,1.2,1.4,1.8,2.0,2.2,2.4
## beta = 1.0
sample1<-rbs(30,0.2,1.0)
sample2<-rbs(30,0.4,1.0)
sample3<-rbs(30,0.6,1.0)
sample4<-rbs(30,0.8,1.0)
sample5<-rbs(30,1.0,1.0)
sample6<-rbs(30,1.2,1.0)
sample7<-rbs(30,1.4,1.0)
sample8<-rbs(30,1.6,1.0)
sample9<-rbs(30,1.8,1.0)
sample10<-rbs(30,2.0,1.0)
sample11<-rbs(30,2.2,1.0)
sample12<-rbs(30,2.4,1.0)

x1<-c(beta1bs(sample1),beta2bs(sample1))
x2<-c(beta1bs(sample2),beta2bs(sample2))
x3<-c(beta1bs(sample3),beta2bs(sample3))
x4<-c(beta1bs(sample4),beta2bs(sample4))
x5<-c(beta1bs(sample5),beta2bs(sample5))
x6<-c(beta1bs(sample6),beta2bs(sample6))
```

```
x7<-c(beta1bs(sample7),beta2bs(sample7))
x8<-c(beta1bs(sample8),beta2bs(sample8))
x9<-c(beta1bs(sample9),beta2bs(sample9))
x10<-c(beta1bs(sample10),beta2bs(sample10))
x11<-c(beta1bs(sample11),beta2bs(sample11))
x12<-c(beta1bs(sample12),beta2bs(sample12))
x<-c(x1[1],x2[1],x3[1],x4[1],x5[1],x6[1],x7[1],x8[1],x9[1],x10[1],x11[1],x12[1])
y<-c(x1[2],x2[2],x3[2],x4[2],x5[2],x6[2],x7[2],x8[2],x9[2],x10[2],x11[2],x12[2])

## Generate the graph
plot(x,y,xlab=expression(beta[1]),ylab=expression(beta[2]),col=4,lwd=2.0)
fitbetabs(0.2,2)
fitbetabs(2.4,3)
```

`fitdeltabs` *delta2-delta3 line fit*

Description

The functions `fitbetabs()` and `fitdeltabs()` allow to one to add a fitting line based on an specified value of alpha for these charts.

Usage

```
fitdeltabs(alpha = 1, col = 2)
```

Arguments

`alpha`	Shape parameter of Birnbaum-Saunders distribution.
`col`	Color of line.

Details

Methods of goodness-of-fit based on moments ($\delta_2 - \delta_3$ chart).

Value

Add a line to delta2-delta3 chart.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Leiva, V., Hernández, H., and Riquelme, M. (2006). A New Package for the Birnbaum-Saunders Distribution. Rnews, 6/4, 35-40. (http://www.r-project.org)

Examples

```
## delta2-delta3 chart
## Example: 12 BSD samples have been simulated by using 'rbs()' for the values
## alfa = 0.2,0.4,0.5,0.6,0.8,1.0,1.2,1.4,1.8,2.0,2.2,2.4
## beta = 1.0
sample1<-rbs(30,0.2,1.0)
sample2<-rbs(30,0.4,1.0)
sample3<-rbs(30,0.6,1.0)
sample4<-rbs(30,0.8,1.0)
sample5<-rbs(30,1.0,1.0)
sample6<-rbs(30,1.2,1.0)
sample7<-rbs(30,1.4,1.0)
sample8<-rbs(30,1.6,1.0)
sample9<-rbs(30,1.8,1.0)
sample10<-rbs(30,2.0,1.0)
sample11<-rbs(30,2.2,1.0)
sample12<-rbs(30,2.4,1.0)

x1<-c(delta2bs(sample1),delta3bs(sample1))
x2<-c(delta2bs(sample2),delta3bs(sample2))
x3<-c(delta2bs(sample3),delta3bs(sample3))
x4<-c(delta2bs(sample4),delta3bs(sample4))
x5<-c(delta2bs(sample5),delta3bs(sample5))
x6<-c(delta2bs(sample6),delta3bs(sample6))
x7<-c(delta2bs(sample7),delta3bs(sample7))
x8<-c(delta2bs(sample8),delta3bs(sample8))
x9<-c(delta2bs(sample9),delta3bs(sample9))
x10<-c(delta2bs(sample10),delta3bs(sample10))
x11<-c(delta2bs(sample11),delta3bs(sample11))
x12<-c(delta2bs(sample12),delta3bs(sample12))
x<-c(x1[1],x2[1],x3[1],x4[1],x5[1],x6[1],x7[1],x8[1],x9[1],x10[1],x11[1],x12[1])
y<-c(x1[2],x2[2],x3[2],x4[2],x5[2],x6[2],x7[2],x8[2],x9[2],x10[2],x11[2],x12[2])

## Genera el gráfico
plot(x,y,xlab=expression(delta[2]),ylab=expression(delta[3]),col=4,lwd=2.0)
fitdeltabs(0.2,2)
fitdeltabs(2.4,3)
```

`frabs` *Failure rate average function (fra) for the BSD*

Description

Failure rate average function for the BSD with shape parameter alpha and scale parameter beta.

Usage

```
frabs(x, alpha = 1, beta = 1)
```

Arguments

`x`	Vector of quantiles.
`alpha`	Shape parameter.
`beta`	Scale parameter.

Details

One of the useful indicators in lifetime analysis is the hazard function (h.f.), which is defined by

$$h_T(t) = \frac{f_T(t)}{1 - F_T(t)},\ t > 0,\ 0 < F_T(t) < 1,$$

where $f_T(\cdot)$ and $F_T(\cdot)$ are the pdf and cdf, respectively; see e.g. Johnson, Kotz, and Balakrishnan (1994, p. 640). The behavior of $h_T(t)$ allows one to characterize the aging of the units. For example, if the failure rate is increasing (IFR class), then the units age with time. If $h_T(t)$ is decreasing (DFR class), then the units improve in performance with time. Finally, if $h_T(t)$ is constant, then the lifetime distribution is necessarily the exponential one.

Another aging indicators are the following:

The failure rate average (FRA) of T is given by

$$FRA(t) = \frac{H_T(t)}{t} = \frac{\int_0^t h_T(t)\,dt}{t},\ t > 0,$$

where $H_T(t)$ is the cumulative hazard function. An analysis for FRA(t) on t permits to obtain the IFRA and DFRA classes.

The survival function (s.f.) and the conditional survival of T are defined by

$$R_T(t) = 1 - F_T(t) \quad \text{and} \quad R_T(t|x) = \frac{R_T(t+x)}{R_T(x)},\ t > 0,\ x > 0,\ R_T(\cdot) > 0,$$

respectively, where $F_T(\cdot)$ is the cdf of T. Similarly to $h_T(t)$ and $FRA(t)$, the distribution of T belongs to the new better than used (NBU), exponential, or new worse than used (NWU) classes, when $R_T(t|x) < R_T(t)$, $R_T(t|x) = R_T(t)$, or $R_T(t|x) > R_T(t)$, respectively.

Value

Failure rate average function for the BSD.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Hoyland, A. and Rausand, M. (1994). System Reliability Theory. John Wiley and Sons. N. Y.

Examples

```
## Reliability indicators:

## Reliability function
rfbs(3,0.5,1.0)

## Conditional reliability function
crfbs(3,0,0.5,1.0)

## Conditional reliability function (age component=0)
crfbs(3,x=0,0.5,1.0)

## Conditional reliability function (age component=0)
crfbs(3,x=2,0.5,1.0)

## failure rate
frbs(3,0.5,1.0)

## failure rate average
frabs(3,0.5,1.0)
```

`frbs` *Failure rate function (fr) for the BSD*

Description

Failure rate function for the BSD with shape parameter alpha and scale parameter beta.

Usage

```
frbs(x, alpha = 1, beta = 1)
```

Arguments

`x`	Vector of quantiles.
`alpha`	Shape parameter.
`beta`	Scale parameter.

Details

One of the useful indicators in lifetime analysis is the hazard function (h.f.), which is defined by

$$h_T(t) = \frac{f_T(t)}{1 - F_T(t)},\ t > 0,\ 0 < F_T(t) < 1,$$

where $f_T(\cdot)$ and $F_T(\cdot)$ are the pdf and cdf, respectively; see e.g. Johnson, Kotz, and Balakrishnan (1994, p. 640). The behavior of $h_T(t)$ allows one to characterize the aging of the units. For example, if the failure rate is increasing (IFR class), then the units age with time. If $h_T(t)$ is decreasing (DFR class), then the units improve in performance with time. Finally, if $h_T(t)$ is constant, then the lifetime distribution is necessarily the exponential one.

Another aging indicators are the following:

The failure rate average (FRA) of T is given by

$$FRA(t) = \frac{H_T(t)}{t} = \frac{\int_0^t h_T(t)\,dt}{t},\ t > 0,$$

where $H_T(t)$ is the cumulative hazard function. An analysis for FRA(t) on t permits to obtain the IFRA and DFRA classes.

The survival function (s.f.) and the conditional survival of T are defined by

$$R_T(t) = 1 - F_T(t) \quad \text{and} \quad R_T(t|x) = \frac{R_T(t+x)}{R_T(x)},\ t > 0,\ x > 0,\ R_T(\cdot) > 0,$$

respectively, where $F_T(\cdot)$ is the cdf of T. Similarly to $h_T(t)$ and $FRA(t)$, the distribution of T belongs to the new better than used (NBU), exponential, or new worse than used (NWU) classes, when $R_T(t|x) < R_T(t)$, $R_T(t|x) = R_T(t)$, or $R_T(t|x) > R_T(t)$, respectively.

Value

Failure rate function for the BSD.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Hoyland, A. and Rausand, M. (1994). System Reliability Theory. John Wiley and Sons. N. Y.

Examples

```
## Reliability indicators:

## Reliability function
rfbs(3,0.5,1.0)

## Conditional reliability function
crfbs(3,0,0.5,1.0)

## Conditional reliability function (age component=0)
crfbs(3,x=0,0.5,1.0)

## Conditional reliability function (age component=0)
crfbs(3,x=2,0.5,1.0)

## failure rate
frbs(3,0.5,1.0)
```

```
## failure rate average
frabs(3,0.5,1.0)
```

---

gmbs *Graphical method estimation (GME) plot*

Description

The function `gmbs()` estimates the parameters alpha and beta of the BSD from a sample of observations by using the graphical method (GME) developed by Chang and Tang (1994). In addition, the function `gmbs()` produces a GME plot for the BSD based on the least squares method.

Usage

```
gmbs(x)
```

Arguments

`x`	Vector of observations.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

D.S. Chang and L.C. Tang (1994). Graphical analysis for Birnbaum-Saunders distribution. Microelectronics and Reliability, 34(1): 17-22.

Examples

```
## Load data sets
data(psi31)
sample<-psi31

gmbs(sample)
```

grapfrbs *Visualization of five different fr's*

Description

The command `graphdbs()` allows the visualization of five different fr's from the BSD, but the legend of this must be added.

Usage

```
grapfrbs(a1, a2, a3, a4, a5, b1, b2, b3, b4, b5)
```

Arguments

`a1`	Shape parameter (first plot).
`a2`	Shape parameter (second plot).
`a3`	Shape parameter (third plot).
`a4`	Shape parameter (fourth plot).
`a5`	Shape parameter (fifth plot).
`b1`	Scale parameter (first plot).
`b2`	Scale parameter (second plot).
`b3`	Scale parameter (third plot).
`b4`	Scale parameter (fourth plot).
`b5`	Scale parameter (first plot).

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

Examples

```
## Figure of pdf's
graphdbs(0.5,0.7,0.9,1.5,2.0,1.0,1.0,1.0,1.0,1.0)

## Legend
legend(3.45,1.25,
c(
"alpha = 0.5",
"alpha = 0.7",
"alpha = 0.9",
"alpha = 1.5",
"alpha = 2.0"),
lty=c(1,1,1,1,1),lwd=c(2,2,2,2,2),
col=c(1,2,3,4,8))
```

```
## Figure of fr's
grapfrbs(0.5,0.7,0.9,1.5,2.0,1.0,1.0,1.0,1.0,1.0)

## Legend
legend(3.425,1.875,
c(
"alpha = 0.5",
"alpha = 0.7",
"alpha = 0.9",
"alpha = 1.5",
"alpha = 2.0"),
lty=c(1,1,1,1,1),lwd=c(2,2,2,2,2),
col=c(1,2,3,4,8))
```

`graphdbs` *Visualization of five different pdf's*

Description

The command `graphdbs()` allows the visualization of five different pdf's from the BSD, but the legend of this must be added.

Usage

```
graphdbs(a1, a2, a3, a4, a5, b1, b2, b3, b4, b5)
```

Arguments

`a1`	Shape parameter (first plot).
`a2`	Shape parameter (second plot).
`a3`	Shape parameter (third plot).
`a4`	Shape parameter (fourth plot).
`a5`	Shape parameter (fifth plot).
`b1`	Scale parameter (first plot).
`b2`	Scale parameter (second plot).
`b3`	Scale parameter (third plot).
`b4`	Scale parameter (fourth plot).
`b5`	Scale parameter (first plot).

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

Examples

```
## Figure of pdf's
graphdbs(0.5,0.7,0.9,1.5,2.0,1.0,1.0,1.0,1.0,1.0)

## Legend
legend(3.45,1.25,
c(
"alpha = 0.5",
"alpha = 0.7",
"alpha = 0.9",
"alpha = 1.5",
"alpha = 2.0"),
lty=c(1,1,1,1,1),lwd=c(2,2,2,2,2),
col=c(1,2,3,4,8))

## Figure of fr's
grapfrbs(0.5,0.7,0.9,1.5,2.0,1.0,1.0,1.0,1.0,1.0)

## Legend
legend(3.425,1.875,
c(
"alpha = 0.5",
"alpha = 0.7",
"alpha = 0.9",
"alpha = 1.5",
"alpha = 2.0"),
lty=c(1,1,1,1,1),lwd=c(2,2,2,2,2),
col=c(1,2,3,4,8))
```

`hqbs` *Hannan-Queen information criterium (HQC) for a sample of the BSD*

Description

The function `hqbs()` gives the HQC value assuming an BSD with parameters alpha and beta. `hqbs()` is based on the invariance property of the MLE.

Usage

```
hqbs(x)
```

Arguments

x	Vector of observations.

Details

The SIC is a selection model criterion based on information loss. According to this criterion, it is possible to choose a hypothetic model that better describe the data set considering the smaller SIC value. The SIC is defined as $SIC = -l(\theta)/n + p\log(n)/(2n)$, where $l(\theta)$ is the log-likelihood function associated with the model, n is the sample size, and p is the number of involved parameters; for more details see Spieglhaiter, Best, Carlin and van der Linde (2002). HQC is a alternative information criterium.

Value

The function `hqbs()` gives the AIC value.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Schwarz, S. (1978). Estimating the dimension of the model. Annals of Statistics, 6, 461-464.

Spieglhaiter, D. J., Best, N. G., Carlin, B. P. and van der Linde, A. (2002). Bayesian measures of complexity and fit. Journal of the Royal Statistical Society Series B 64, 1-34.

Leiva, V., Hernández, H., and Riquelme, M. (2006). A New Package for the Birnbaum-Saunders Distribution. Rnews, 6/4, 35-40. (http://www.r-project.org)

Examples

```
## Load data sets
data(psi31)

## Calculus of HQC for psi31
hqbs(psi31)
```

---

indicatorsbs *Indicators for the Birbaum-Saunders distribution*

Description

The function `indicatorsbs()` computes the MLE's for alpha, beta, mean, variance, CV, CS and CK for the BSD.

Usage

```
indicatorsbs(x)
```

Arguments

`x`	Vector of observations.

Details

By using the invariance property of the MLE's, we obtain estimations for the mean, the variance, and the coefficients of variation (CV), skewness (CS), and kurtosis (CK).

Value

The function `indicatorsbs()` gives a list of estimations for the alpha, beta, mean, variance, CV, CS, and CK of BSD.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Leiva, V., Hernández, H., and Riquelme, M. (2006). A New Package for the Birnbaum-Saunders Distribution. Rnews, 6/4, 35-40. (http://www.r-project.org)

Examples

```
## Summary for psi31
data(psi31)
sample<-psi31
indicatorsbs(sample)
```

`ksbs` *Test of Kolmogorov-Smirnov for the Birnbaum-Saunders distribution*

Description

The function `ksbs()` gives the values for the KS test assuming an BSD with shape parameter alpha and scale parameter beta. In addition, optionally, this function allows one to show a comparative graph between the empirical and theoretical cdfs for a specified data set.

Usage

```
ksbs(x, alternative = c("less", "two.sided", "greater"), plot = FALSE)
```

Arguments

`x`	Vector of observations.
`alternative`	indicates the alternative hypothesis and must be one of `"two.sided"` (default), `"less"`, or `"greater"`.
`plot`	Logical; if TRUE, the cdf plot is provided.

Details

The Kolmogorov-Smirnov test is a goodness-of-fit technique based on the maximum distance between the empirical and theoretical cdfs.

Value

The function `ksbs()` carries out the KS test for the BSD.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

Examples

```
## Load data sets
data(psi31)
sample<-psi31

## KS test for psi31
ksbs(sample,plot=FALSE,alternative="two.sided")
```

`pbs` *Cumulative distribution function (cdf) of the Birnbaum-Saunders distribution*

Description

Cumulative distribution function of the BSD with shape parameter alpha and scale parameter beta.

Usage

```
pbs(q, alpha = 1, beta = 1, lower.tail = TRUE, log.p = FALSE)
```

Arguments

`q`	Vector of quantiles.
`alpha`	Shape parameter.
`beta`	Scale parameter.
`lower.tail`	Logical; if TRUE (default), probabilities are P[X <= x], otherwise, P[X > x].
`log.p`	Logical; if TRUE, probabilities p are given as log(p).

Details

Birnbaum and Saunders (1969) proposed the two-parameter Birnbaum-Saunders distribution with density

$$f_T(t) = \frac{1}{\sqrt{2\pi}} \exp\left[-\frac{1}{2\alpha^2}\left(\frac{t}{\beta} + \frac{\beta}{t} - 2\right)\right] \frac{t^{-\frac{3}{2}}(t+\beta)}{2\alpha\sqrt{\beta}};\ t > 0, \alpha > 0, \beta > 0,$$

as a failure time distribution for fatigue failure caused under cyclic loading. The parameters alpha and beta are the shape and the scale parameters, respectively. In their derivation, it was assumed that the failure is due to the development and growth of a dominant crack.

Value

`pbs()` gives the cdf of an BSD.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Birnbaum, Z. W. and Saunders, S. C. (1969). A new family of life distributions. J. Appl. Probab. 6(2): 637-652.

Examples

```
## Load package
library(bs)

## cdf for the Birnbaum-Saunders distribution
## with parameters alpha=0.5 y beta=1.0 in x=3.
pbs(3,alpha=0.5,beta=1.0,log=FALSE)
```

---

ppbs — *Probability versus probability (PP) plot for the BSD*

Description

The function `ppbs()` produces a PP plot for the BSD based on their MLE. Also, a line going through the first and the third quartile can be sketched. In addition, the coefficient of determination of the least square method for the fit line is given.

Usage

```
ppbs(x, line = FALSE, xlab = "Empirical distribution function", ylab = "Theorical c
```

Arguments

x	Vector of observations.
line	Logical; if TRUE, a line going by the first and third quartile is sketched.
xlab	A title for the x axis.
ylab	A title for the y axis.

Value

The function `ppbs()` carries out a PP plot for the IGTD.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Birnbaum, Z. W. and Saunders, S. C. (1969). A new family of life distributions. J. Appl. Probab. 6(2): 637-652.

Examples

```
## Load data sets
data(psi31)
sample<-psi31

## QQ plot for psi31
qqbs(sample,line=TRUE)

## PP plot for psi31
ppbs(sample,line=TRUE)
```

---

psi21 — *Lifetimes of aluminum specimens exposed to a maximum stress of 21,000 psi.*

Description

Several data sets related to the BSD are available in the bs package, which have been taken from the literature on this topic.

Usage

```
data(psi21)
```

Format

A vector containing 101 observations.

Details

psi21, psi26 and psi31 were taken from Birnbaum and Saunders (1969), who reported fatigue life data correspond to the cycles ($\times 10^{-3}$) of aluminum specimens of type 6061-T6. These specimens were cut in a parallel angle to the direction of rotation and oscillating at 18 cycles per seconds. They were exposed to a pressure with maximum stress of 21,000, 26,000, and 31,000 psi (pounds per square inch), for $n = 101, 102$, and 101 specimens, respectively.

References

Birnbaum, Z. W. and Saunders, S. C. (1969). Estimation for a family of life distributions with applications to fatigue. J. Appl. Probab. 6(2): 328-347.

Examples

```
## Load data sets
data(psi21)
## Histogram for psi21
hist(psi21)
```

---

psi26 *Lifetimes of aluminum specimens exposed to a maximum stress of 26,000 psi.*

Description

Several data sets related to the BSD are available in the bs package, which have been taken from the literature on this topic.

Usage

```
data(psi26)
```

Format

A vector containing 102 observations.

Details

psi21, psi26 and psi31 were taken from Birnbaum and Saunders (1969), who reported fatigue life data correspond to the cycles ($\times 10^{-3}$) of aluminum specimens of type 6061-T6. These specimens were cut in a parallel angle to the direction of rotation and oscillating at 18 cycles per seconds. They were exposed to a pressure with maximum stress of 21,000, 26,000, and 31,000 psi (pounds per square inch), for $n = 101, 102$, and 101 specimens, respectively.

References

Birnbaum, Z. W. and Saunders, S. C. (1969). Estimation for a family of life distributions with applications to fatigue. J. Appl. Probab. 6(2): 328-347.

Examples

```
## Load data sets
data(psi26)
## Histogram for psi26
hist(psi26)
```

`psi31` *Lifetimes of aluminum specimens exposed to a maximum stress of 31,000 psi.*

Description

Several data sets related to the BSD are available in the bs package, which have been taken from the literature on this topic.

Usage

```
data(psi31)
```

Format

A vector containing 101 observations.

Details

psi21, psi26 and psi31 were taken from Birnbaum and Saunders (1969), who reported fatigue life data correspond to the cycles ($\times 10^{-3}$) of aluminum specimens of type 6061-T6. These specimens were cut in a parallel angle to the direction of rotation and oscillating at 18 cycles per seconds. They were exposed to a pressure with maximum stress of 21,000, 26,000, and 31,000 psi (pounds per square inch), for $n = 101, 102$, and 101 specimens, respectively.

References

Birnbaum, Z. W. and Saunders, S. C. (1969). Estimation for a family of life distributions with applications to fatigue. J. Appl. Probab. 6(2): 328-347.

Examples

```
## Load data sets
data(psi31)
## Histogram for psi31
hist(psi31)
```

qbs *Quantile function (qf) of the Birnbaum-Saunders distribution*

Description

Quantile function of the BSD with shape parameter alpha and scale parameter beta.

Usage

```
qbs(p, alpha = 1, beta = 1, lower.tail = TRUE, log.p = FALSE)
```

Arguments

`p`	Vector of probabilities.
`alpha`	Shape parameter.
`beta`	Scale parameter.
`lower.tail`	Logical; if TRUE (default), probabilities are P[X <= x], otherwise, P[X > x].
`log.p`	Logical; if TRUE, probabilities p are given as log(p).

Details

Birnbaum and Saunders (1969) proposed the two-parameter Birnbaum-Saunders distribution with density

$$f_T(t) = \frac{1}{\sqrt{2\pi}} \exp\left[-\frac{1}{2\alpha^2}\left(\frac{t}{\beta} + \frac{\beta}{t} - 2\right)\right] \frac{t^{-\frac{3}{2}}(t+\beta)}{2\alpha\sqrt{\beta}};\ t > 0, \alpha > 0, \beta > 0,$$

as a failure time distribution for fatigue failure caused under cyclic loading. The parameters alpha and bata are the shape and the scale parameters, respectively. In their derivation, it was assumed that the failure is due to the development and growth of a dominant crack.

Value

`qbs()` gives the qf of an BSD.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Birnbaum, Z. W. and Saunders, S. C. (1969). A new family of life distributions. J. Appl. Probab. 6(2): 637-652.

Examples

```
## Load package
library(bs)

## cuantil function for p=0.5 in the BSD
## with parameters alpha=0.5 y beta=1.0.
pbs(0.5,alpha=0.5,beta=1.0,log=FALSE)
```

`qqbs` *Quantile versus quantile (QQ) plot for the the BSD*

Description

The function `qqbs()` produces a QQ plot for the BSD based on their MLE. Also, a line going through the first and the third quartile can be sketched.

Usage

```
qqbs(x, line = FALSE, xlab = "Empirical quantiles", ylab = "Theoretical quantiles")
```

Arguments

`x`	Vector of observations.
`line`	Logical; if TRUE, a line going by the first and third quartile is sketched.
`xlab`	A title for the x axis.
`ylab`	A title for the y axis.

Value

The function `qqbs()` carries out a QQ plot for the BSD.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Birnbaum, Z. W. and Saunders, S. C. (1969). A new family of life distributions. J. Appl. Probab. 6(2): 637-652.

Examples

```
## Load data sets
data(psi31)
sample<-psi31

## QQ plot for psi31
qqbs(sample,line=TRUE)

## PP plot for psi31
ppbs(sample,line=TRUE)
```

`rbs` *Random number generator from the Birnbaum-Saunders distribution*

Description

Generate random numbers from the BSD with shape parameter alpha and scale parameter beta. The function `rbs()` selects the most appropriate method automatically. For details about effectiveness and efficiency of these three generators and the way to select the most suitable one see Leiva et al. (2006).

Usage

```
rbs(n, alpha = 1, beta = 1)
```

Arguments

`n`	Number of observations.
`alpha`	Shape parameter.
`beta`	Scale parameter.

Details

Birnbaum and Saunders (1969) proposed the two-parameter Birnbaum-Saunders distribution with density

$$f_T(t) = \frac{1}{\sqrt{2\pi}} \exp\left[-\frac{1}{2\alpha^2}\left(\frac{t}{\beta} + \frac{\beta}{t} - 2\right)\right] \frac{t^{-\frac{3}{2}}(t+\beta)}{2\alpha\sqrt{\beta}};\ t > 0, \alpha > 0, \beta > 0,$$

as a failure time distribution for fatigue failure caused under cyclic loading. The parameters alpha and bata are the shape and the scale parameters, respectively. In their derivation, it was assumed that the failure is due to the development and growth of a dominant crack.

Value

`rbs()` gives a vector of n random numbers from the BSD with specific values of alpha and beta.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Chang D. S. and Tang, L. C. (1994). Random number generator for the Birnbaum-Saunders distribution. Computational and Industrial Engineering, 27(1-4):345-348.

Leiva, V., Sanhueza, A., Sen, P. K., and Paula, G. A. (2006). Random number generators for the generalized Birnbaum-Saunders distribution. Submitted to Publication.

Rieck, J. R. (2003). A comparison of two random number generators for the Birnbaum-Saunders distribution. Communications in Statistics - Theory and Methods, 32(5):929-934.

Examples

```
## Examples for simulations
rbs1(n=6,alpha=0.5,beta=1.0)
rbs2(n=6,alpha=0.5,beta=1.0)
rbs3(n=6,alpha=0.5,beta=1.0)

rbs(n=6,alpha=0.5,beta=1.0)

sample<-rbs(n=100,alpha=0.5,beta=1.0)
## Higtogram for sample
hist(sample)
```

---

rbs1 *Random number generator from BSD (G1)*

Description

Generate random numbers from the BSD with shape parameter alpha and scale parameter beta. `rbs1()` is based on the relationship between the standard normal distribution and the BSD; see Chang and Tang (1994).

Usage

```
rbs1(n, alpha = 1, beta = 1)
```

Arguments

`n`	Number of observations.
`alpha`	Shape parameter.
`beta`	Scale parameter.

Value

`rbs1()` gives a vector of n random numbers from the BSD for alpha and beta.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Chang D. S. and Tang, L. C. (1994). Random number generator for the Birnbaum-Saunders distribution. Computational and Industrial Engineering, 27(1-4):345-348.

Examples

```
## Examples for simulations
rbs1(n=6,alpha=0.5,beta=1.0)
rbs2(n=6,alpha=0.5,beta=1.0)
rbs3(n=6,alpha=0.5,beta=1.0)

rbs(n=6,alpha=0.5,beta=1.0)

sample<-rbs(n=100,alpha=0.5,beta=1.0)
## Higtogram for sample
hist(sample)
```

---

rbs2 *Random number generator from BSD (G2)*

Description

Generate random numbers from the BSD with shape parameter alpha and scale parameter beta. `rbs2()` is based on the relationship between the sinhnormal distribution (SHND) and the BSD; see Rieck (2003).

Usage

```
rbs2(n, alpha = 1, beta = 1)
```

Arguments

`n`	Number of observations.
`alpha`	Shape parameter.
`beta`	Scale parameter.

Value

`rbs2()` gives a vector of n random numbers from the BSD with specific values alpha and beta.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Rieck, J. R. (2003). A comparison of two random number generators for the Birnbaum-Saunders distribution. Communications in Statistics - Theory and Methods, 32(5):929-934.

Examples

```
## Examples for simulations
rbs1(n=6,alpha=0.5,beta=1.0)
rbs2(n=6,alpha=0.5,beta=1.0)
rbs3(n=6,alpha=0.5,beta=1.0)

rbs(n=6,alpha=0.5,beta=1.0)

sample<-rbs(n=100,alpha=0.5,beta=1.0)
## Higtogram for sample
hist(sample)
```

---

rbs3 — *Random number generator from BSD (G3)*

Description

Generate random numbers from the BSD with shape parameter alpha and scale parameter beta. `rbs3()` is based on the relationship between the inverse Gaussian distribution (IGD) and the BSD; see Johnson et al. (1994).

Usage

```
rbs3(n, alpha = 1, beta = 1)
```

Arguments

`n`	Number of observations.
`alpha`	Shape parameter.
`beta`	Scale parameter.

Value

`rbs3()` gives a vector of n random numbers from the BSD with specific values alpha and beta.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Johnson, N. L., Kotz, S. and Balakrishnan, N. (1994). Continuous Univariate Distributions: Volume 2. Wiley, New York.

Leiva, V., Sanhueza, A., Sen, P. K., and Paula, G. A. (2006). Random number generators for the generalized Birnbaum-Saunders distribution. Submitted to Publication.

Examples

```
## Examples for simulations
rbs1(n=6,alpha=0.5,beta=1.0)
rbs2(n=6,alpha=0.5,beta=1.0)
rbs3(n=6,alpha=0.5,beta=1.0)

rbs(n=6,alpha=0.5,beta=1.0)

sample<-rbs(n=100,alpha=0.5,beta=1.0)
## Higtogram for sample
hist(sample)
```

---

rfbs *Reliability function (rf) of the BSD*

Description

Survival function (or reliability function) of the BSD with shape parameter alpha and scale parameter beta.

Usage

```
rfbs(x, alpha = 1, beta = 1)
```

Arguments

x	Vector of quantiles.
alpha	Shape parameter.
beta	Scale parameter.

Details

One of the useful indicators in lifetime analysis is the hazard function (h.f.), which is defined by

$$h_T(t) = \frac{f_T(t)}{1 - F_T(t)},\ t > 0,\ 0 < F_T(t) < 1,$$

where $f_T(\cdot)$ and $F_T(\cdot)$ are the pdf and cdf, respectively; see e.g. Johnson, Kotz, and Balakrishnan (1994, p. 640). The behavior of $h_T(t)$ allows one to characterize the aging of the units. For example, if the failure rate is increasing (IFR class), then the units age with time. If $h_T(t)$ is decreasing (DFR class), then the units improve in performance with time. Finally, if $h_T(t)$ is constant, then the lifetime distribution is necessarily the exponential one.

Another aging indicators are the following:

The failure rate average (FRA) of T is given by

$$FRA(t) = \frac{H_T(t)}{t} = \frac{\int_0^t h_T(t)\,dt}{t},\ t > 0,$$

where $H_T(t)$ is the cumulative hazard function. An analysis for FRA(t) on t permits to obtain the IFRA and DFRA classes.

The survival function (s.f.) and the conditional survival of T are defined by

$$R_T(t) = 1 - F_T(t) \quad \text{and} \quad R_T(t|x) = \frac{R_T(t+x)}{R_T(x)},\ t > 0,\ x > 0,\ R_T(\cdot) > 0,$$

respectively, where $F_T(\cdot)$ is the cdf of T. Similarly to $h_T(t)$ and $FRA(t)$, the distribution of T belongs to the new better than used (NBU), exponential, or new worse than used (NWU) classes, when $R_T(t|x) < R_T(t)$, $R_T(t|x) = R_T(t)$, or $R_T(t|x) > R_T(t)$, respectively.

Value

Survival function for the BSD.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Hoyland, A. and Rausand, M. (1994). System Reliability Theory. John Wiley and Sons. N. Y.

Examples

```
## Reliability indicators:

## Reliability function
rfbs(3,0.5,1.0)

## Conditional reliability function
crfbs(3,0,0.5,1.0)
```

```
## Conditional reliability function (age component=0)
crfbs(3,x=0,0.5,1.0)

## Conditional reliability function (age component=0)
crfbs(3,x=2,0.5,1.0)

## failure rate
frbs(3,0.5,1.0)

## failure rate average
frabs(3,0.5,1.0)
```

`sicbs` *Schwartz information criterium (SIC) for a sample of the BSD*

Description

The function `sicbs()` gives the SIC value assuming an BSD with parameters alpha and beta. `sicbs()` is based on the invariance property of the MLE.

Usage

```
sicbs(x)
```

Arguments

`x`	Vector of observations.

Details

The SIC is a selection model criterion based on information loss. According to this criterion, it is possible to choose a hypothetic model that better describe to the data set considering the smaller SIC value. The SIC is defined as $SIC = -l(\theta)/n + p\log(n)/(2n)$, where $l(\theta)$ is the log-likelihood function associated with the model, n is the sample size, and p is the number of involved parameters; for more details see Spieglhaiter, Best, Carlin and van der Linde (2002).

Value

The function `sicbs()` gives the SIC value.

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Schwarz, S. (1978). Estimating the dimension of the model. Annals of Statistics, 6, 461-464.

Spieglhaiter, D. J., Best, N. G., Carlin, B. P. and van der Linde, A. (2002). Bayesian measures of complexity and fit. Journal of the Royal Statistical Society Series B 64, 1-34.

Leiva, V., Hernández, H., and Riquelme, M. (2006). A New Package for the Birnbaum-Saunders Distribution. Rnews, 6/4, 35-40. (http://www.r-project.org)

Examples

```
## Load data sets
data(psi31)

## Calculus of SIC for psi31
sicbs(psi31)
```

`simul.bs.gme` *Simulation study by using GME method*

Description

The function `simul.bs.gme()` simulates three samples of size n from a population $T \sim \mathrm{BS}(\mathrm{alpha}, \mathrm{beta})$, one for each method (`rbs1()`, `rbs2()`, or `rbs3()`), computes the GMES's for alpha and beta, and establish goodness-of-fit for each sample.

Usage

```
simul.bs.gme(n, alpha, beta)
```

Arguments

`n`	Samples of size `n`.
`alpha`	Teorical shape parameter for simulations.
`beta`	Teorical scale parameter for simulations.

Details

In order to carry out simulation studies, we develop the functions `simul.bs.gme()`, `simul.bs.mle()`, and `simul.bs.mme()`. These functions generate random samples, estimate parameters, and establish goodness-of-fit. The samples of size n, one for each method (G1, G2, or G3), are generated by using `rbs1()`, `rbs2()`, and `rbs3()`, respectively. The estimations, one for each method, are obtained by using `est1bs()`, `est2bs()`, and `est3bs()`, respectively. The goodness-of-fit method is based on the statistic of Kolmogorov-Smirnov (KS), which is available through the function `ksbs()`. The generated observations by means of G1, G2, and G3 are saved as slots of the `R class simulBsClass`, which are named `sample1`, `sample2`, and `sample3`, respectively. Furthermore, the results of the simulation study are saved in a fourth slot of this class, named `results`.

Value

An object of class "simulBsClass" (Slots).

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Leiva, V., Hernández, H., and Riquelme, M. (2006). A New Package for the Birnbaum-Saunders Distribution. Rnews, 6/4, 35-40. (http://www.r-project.org)

Examples

```
## Example: simul.bs.mle()
simul.bs.mle(100,0.5,1.0)

results<-simul.bs.mle(100,0.5,1.0)
results@results

sample<-results@sample1

## Example: simul.bs.mme()
simul.bs.mme(100,0.5,1.0)

## Example: simul.bs.gme()
simul.bs.gme(100,0.5,1.0)
```

---

simul.bs.mle *Simulation study by using MLE method*

Description

The function simul.bs.mle() simulates three samples of size n from a population $T \sim \mathrm{BS}(\mathrm{alpha}, \mathrm{beta})$, one for each method (rbs1(), rbs2(), or rbs3()), computes the MLES's for alpha and beta, and establish goodness-of-fit for each sample.

Usage

```
simul.bs.mle(n, alpha, beta)
```

Arguments

n	Samples of size n.
alpha	Teorical shape parameter for simulations.
beta	Teorical scale parameter for simulations.

Details

In order to carry out simulation studies, we develop the functions `simul.bs.gme()`, `simul.bs.mle()`, and `simul.bs.mme()`. These functions generate random samples, estimate parameters, and establish goodness-of-fit. The samples of size n, one for each method (G1, G2, or G3), are generated by using `rbs1()`, `rbs2()`, and `rbs3()`, respectively. The estimations, one for each method, are obtained by using `est1bs()`, `est2bs()`, and `est3bs()`, respectively. The goodness-of-fit method is based on the statistic of Kolmogorov-Smirnov (KS), which is available through the function `ksbs()`. The generated observations by means of G1, G2, and G3 are saved as slots of the `R class simulBsClass`, which are named `sample1`, `sample2`, and `sample3`, respectively. Furthermore, the results of the simulation study are saved in a fourth slot of this class, named `results`.

Value

An object of class `"simulBsClass"` (Slots).

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Leiva, V., Hernández, H., and Riquelme, M. (2006). A New Package for the Birnbaum-Saunders Distribution. Rnews, 6/4, 35-40. (http://www.r-project.org)

Examples

```
## Example: simul.bs.mle()
simul.bs.mle(100,0.5,1.0)

results<-simul.bs.mle(100,0.5,1.0)
results@results

sample<-results@sample1

## Example: simul.bs.mme()
simul.bs.mme(100,0.5,1.0)

## Example: simul.bs.gme()
simul.bs.gme(100,0.5,1.0)
```

`simul.bs.mme` *Simulation study by using MME method*

Description

The function `simul.bs.mme()` simulates three samples of size n from a population $T \sim \mathrm{BS}(\mathrm{alpha}, \mathrm{beta})$, one for each method (`rbs1()`, `rbs2()`, or `rbs3()`), computes the MMES's for alpha and beta, and establish goodness-of-fit for each sample.

Usage

```
simul.bs.mme(n, alpha, beta)
```

Arguments

`n`	Samples of size `n`.
`alpha`	Teorical shape parameter for simulations.
`beta`	Teorical scale parameter for simulations.

Details

In order to carry out simulation studies, we develop the functions `simul.bs.gme()`, `simul.bs.mle()`, and `simul.bs.mme()`. These functions generate random samples, estimate parameters, and establish goodness-of-fit. The samples of size n, one for each method (G1, G2, or G3), are generated by using `rbs1()`, `rbs2()`, and `rbs3()`, respectively. The estimations, one for each method, are obtained by using `est1bs()`, `est2bs()`, and `est3bs()`, respectively. The goodness-of-fit method is based on the statistic of Kolmogorov-Smirnov (KS), which is available through the function `ksbs()`. The generated observations by means of G1, G2, and G3 are saved as slots of the `R class simulBsClass`, which are named `sample1`, `sample2`, and `sample3`, respectively. Furthermore, the results of the simulation study are saved in a fourth slot of this class, named `results`.

Value

An object of class `"simulBsClass"` (Slots).

Author(s)

Víctor Leiva <victor.leiva@uv.cl>, Hugo Hernández <hugo.hernande@msn.com>, and Marco Riquelme <mriquelm@ucm.cl>.

References

Leiva, V., Hernández, H., and Riquelme, M. (2006). A New Package for the Birnbaum-Saunders Distribution. Rnews, 6/4, 35-40. (http://www.r-project.org)

Examples

```
## Example: simul.bs.mle()
simul.bs.mle(100,0.5,1.0)

results<-simul.bs.mle(100,0.5,1.0)
results@results
```

```
sample<-results@sample1

## Example: simul.bs.mme()
simul.bs.mme(100,0.5,1.0)

## Example: simul.bs.gme()
simul.bs.gme(100,0.5,1.0)
```

`timerepair` *Maintenance data*

Description

Several data sets related to the BSD are available in the bs package, which have been taken from the literature on this topic.

Usage

```
data(timerepair)
```

Format

A vector containing 46 observations.

Details

`timerepair` correspond to maintenance data on active repair times (in hours) for an airborne communications transceiver.

References

Hsieh, H. K. (1990). Estimating the Critical Time of Inverse Gaussian Hazard Rate. IEEE Transactions on Reliability, 39(10): 342-345.

Examples

```
## Load data sets
data(timerepair)
## Histogram for timerepair
hist(timerepair)
```

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