Package 'Reliability'

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Title Functions for estimating parameters in software reliability models

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Depends R (>= 2.4.0)

Description Functions for estimating parameters in software reliability models. Only infinite failure models are implemented so far.

License Unlimited

NeedsCompilation no

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R topics documented:

duane *Maximum Likelihood estimation of mean value function for Duane model*

Description

duane computes the Maximum Likelihood estimates for the parameters rho and theta of the mean value function for the Duane model.

Usage

```
duane(t, init = c(1, 1), method = "Nelder-Mead", maxit = 10000, ...)
```

Arguments

t	time between failure data
init	initial values for Maximum Likelihood fit of the mean value function for the Duane model.
method	the method to be used for optimization, see optim for details.
maxit	the maximum number of iterations, see optim for details.
...	control parameters and plot parameters optionally passed to the optimization and/or plot function. Parameters for the optimization function are passed to components of the control argument of optim.

Details

This function estimates the parameters rho and theta of the mean value function for the Duane model. With Maximum Likelihood estimation one gets the following equations, which have to be minimized. This is

$$equation_1 := \rho - \frac{n}{t_n^\theta} = 0$$

and

$$equation_2 := \theta - \frac{n}{\sum_{i=1}^{n-1}(\log(t_n/t_i))} = 0.$$

Where t is the time between failure data and n is the length or in other words the size of the time between failure data. So the simultaneous minimization of these equations happens by minimization of the equation

$$equation_1^2 + equation_2^2 = 0.$$

Value

A list containing following components:

rho	Maximum Likelihood estimate for rho
theta	Maximum Likelihood estimate for theta

Author(s)

Andreas Wittmann <andreas_wittmann@gmx.de>

References

J.D. Musa, A. Iannino, and K. Okumoto. *Software Reliability: Measurement, Prediction, Application*. McGraw-Hill, 1987.

Michael R. Lyu. *Handbook of Software Realibility Engineering*. IEEE Computer Society Press, 1996. http://www.cse.cuhk.edu.hk/~lyu/book/reliability/

See Also

duane.plot, mvf.duane

Examples

```
# time between-failure-data from DACS Software Reliability Dataset
# homepage, see system code 1. Number of failures is 136.
t <- c(3, 30, 113, 81, 115, 9, 2, 20, 20, 15, 138, 50, 77, 24,
       108, 88, 670, 120, 26, 114, 325, 55, 242, 68, 422, 180,
       10, 1146, 600, 15, 36, 4, 0, 8, 227, 65, 176, 58, 457,
       300, 97, 263, 452, 255, 197, 193, 6, 79, 816, 1351, 148,
       21, 233, 134, 357, 193, 236, 31, 369, 748, 0, 232, 330,
       365, 1222, 543, 10, 16, 529, 379, 44, 129, 810, 290, 300,
       529, 281, 160, 828, 1011, 445, 296, 1755, 1064, 1783,
       860, 983, 707, 33, 868, 724, 2323, 2930, 1461, 843, 12,
       261, 1800, 865, 1435, 30, 143, 108, 0, 3110, 1247, 943,
       700, 875, 245, 729, 1897, 447, 386, 446, 122, 990, 948,
       1082, 22, 75, 482, 5509, 100, 10, 1071, 371, 790, 6150,
       3321, 1045, 648, 5485, 1160, 1864, 4116)

duane(t)
```

---

duane.plot *Plotting the mean value function for the Duane model*

Description

duane.plot plots the mean value function for the Duane model and the raw data into one window.

Usage

```
duane.plot(rho, theta, t, xlab = "time",
    ylab = "Cumulated failures and estimated mean value function",
    main = NULL)
```

Arguments

rho	parameter value for rho
theta	parameter value for theta
t	time between failure data
xlab	a title for the x axis
ylab	a title for the y axis
main	an overall title for the plot

Details

This function gives a plot of the mean value function for the Duane model. Here the estimated parameter values for rho and theta, which are obtained by using duane, can be put in. Internally the function mvf.duane is used to get the mean value function for the Duane model.

Value

A graph of the mean value function for the Duane model and of the raw data.

Author(s)

Andreas Wittmann <andreas_wittmann@gmx.de>

References

J.D. Musa, A. Iannino, and K. Okumoto. *Software Reliability: Measurement, Prediction, Application*. McGraw-Hill, 1987.

Michael R. Lyu. *Handbook of Software Realibility Engineering*. IEEE Computer Society Press, 1996. http://www.cse.cuhk.edu.hk/~lyu/book/reliability/

See Also

duane, mvf.duane

Examples

```
# time between-failure-data from DACS Software Reliability Dataset
# homepage, see system code 1. Number of failures is 136.
t <- c(3, 30, 113, 81, 115, 9, 2, 20, 20, 15, 138, 50, 77, 24,
       108, 88, 670, 120, 26, 114, 325, 55, 242, 68, 422, 180,
       10, 1146, 600, 15, 36, 4, 0, 8, 227, 65, 176, 58, 457,
       300, 97, 263, 452, 255, 197, 193, 6, 79, 816, 1351, 148,
       21, 233, 134, 357, 193, 236, 31, 369, 748, 0, 232, 330,
       365, 1222, 543, 10, 16, 529, 379, 44, 129, 810, 290, 300,
       529, 281, 160, 828, 1011, 445, 296, 1755, 1064, 1783,
       860, 983, 707, 33, 868, 724, 2323, 2930, 1461, 843, 12,
       261, 1800, 865, 1435, 30, 143, 108, 0, 3110, 1247, 943,
       700, 875, 245, 729, 1897, 447, 386, 446, 122, 990, 948,
       1082, 22, 75, 482, 5509, 100, 10, 1071, 371, 790, 6150,
```

```
        3321, 1045, 648, 5485, 1160, 1864, 4116)

rho <- duane(t)$rho
theta <- duane(t)$theta

duane.plot(rho, theta, t, xlab = "time (in seconds)", main = "Duane model")
```

`littlewood.verall` *Maximum Likelihood estimation of mean value function for Littlewood-Verall model*

Description

`littlewood.verall` computes the Maximum Likelihood estimates for the parameters `theta0`, `theta1` and `rho` of the mean value function for the Littlewood-Verall model.

Usage

```
littlewood.verall(t, linear = T, init = c(1, 1, 1), method = "Nelder-Mead",
    maxit = 10000, ...)
```

Arguments

`t`	time between failure data
`linear`	logical. Should the linear or the quadratic form of the mean value function for the Littlewood-Verrall model be used of computation? If `TRUE`, which is the default, the linear form of the mean value function is used.
`init`	initial values for Maximum Likelihood fit of the mean value function for the Littlewood-Verall model.
`method`	the method to be used for optimization, see `optim` for details.
`maxit`	the maximum number of iterations, see `optim` for details.
`...`	control parameters and plot parameters optionally passed to the optimization and/or plot function. Parameters for the optimization function are passed to components of the `control` argument of `optim`.

Details

This function estimates the parameters `theta0`, `theta1` and `rho` of the mean value function in the linear or the quadratic form for the Littlewood-Verall model.

First, the computation with the mean value function in the linear form is explained. With Maximum Likelihood estimation one gets the following equations, which have to be minimized. This is

$$equation_1 := \frac{n}{\rho} + \sum_{i=1}^{n} \log(\theta_0 + \theta_1 i) - \sum_{i=1}^{n} \log(\theta_0 + \theta_1 i + t_i) = 0,$$

$$equation_2 := \rho \sum_{i=1}^{n} \frac{1}{\theta_0 + \theta_1 i} - \rho + 1 \sum_{i=1}^{n} \frac{1}{\theta_0 + \theta_1 i + t_i} = 0$$

and

$$equation_3 := \rho \sum_{i=1}^{n} \frac{i}{\theta_0 + \theta_1 i} - \rho + 1 \sum_{i=1}^{n} \frac{i}{\theta_0 + \theta_1 i + t_i} = 0.$$

Second, the computation with the mean value function in the quadratic form is explained. With Maximum Likelihood estimation one gets the following equations, which have to be minimized. This is

$$equation_1 := \frac{n}{\rho} + \sum_{i=1}^{n} \log(\theta_0 + \theta_1 i^2) - \sum_{i=1}^{n} \log(\theta_0 + \theta_1 i^2 + t_i) = 0,$$

$$equation_2 := \rho \sum_{i=1}^{n} \frac{1}{\theta_0 + \theta_1 i^2} - \rho + 1 \sum_{i=1}^{n} \frac{1}{\theta_0 + \theta_1 i^2 + t_i} = 0$$

and

$$equation_3 := \rho \sum_{i=1}^{n} \frac{i^2}{\theta_0 + \theta_1 i^2} - \rho + 1 \sum_{i=1}^{n} \frac{i^2}{\theta_0 + \theta_1 i^2 + t_i} = 0.$$

Where t is the time between failure data and n is the length or in other words the size of the time between failure data. So the simultaneous minimization of these equations happens by minimization of the equation

$$equation_1^2 + equation_2^2 + equation_3^2 = 0.$$

Value

A list containing following components:

`theta0`	Maximum Likelihood estimate for `theta0`
`theta1`	Maximum Likelihood estimate for `theta1`
`rho`	Maximum Likelihood estimate for `rho`

Author(s)

Andreas Wittmann <andreas_wittmann@gmx.de>

References

J.D. Musa, A. Iannino, and K. Okumoto. *Software Reliability: Measurement, Prediction, Application*. McGraw-Hill, 1987.

Michael R. Lyu. *Handbook of Software Realibility Engineering*. IEEE Computer Society Press, 1996. http://www.cse.cuhk.edu.hk/~lyu/book/reliability/

See Also

littlewood.verall.plot, mvf.ver.lin, mvf.ver.quad

Examples

```
# time between-failure-data from DACS Software Reliability Dataset
# homepage, see system code 1. Number of failures is 136.
t <- c(3, 30, 113, 81, 115, 9, 2, 20, 20, 15, 138, 50, 77, 24,
       108, 88, 670, 120, 26, 114, 325, 55, 242, 68, 422, 180,
       10, 1146, 600, 15, 36, 4, 0, 8, 227, 65, 176, 58, 457,
       300, 97, 263, 452, 255, 197, 193, 6, 79, 816, 1351, 148,
       21, 233, 134, 357, 193, 236, 31, 369, 748, 0, 232, 330,
       365, 1222, 543, 10, 16, 529, 379, 44, 129, 810, 290, 300,
       529, 281, 160, 828, 1011, 445, 296, 1755, 1064, 1783,
       860, 983, 707, 33, 868, 724, 2323, 2930, 1461, 843, 12,
       261, 1800, 865, 1435, 30, 143, 108, 0, 3110, 1247, 943,
       700, 875, 245, 729, 1897, 447, 386, 446, 122, 990, 948,
       1082, 22, 75, 482, 5509, 100, 10, 1071, 371, 790, 6150,
       3321, 1045, 648, 5485, 1160, 1864, 4116)

littlewood.verall(t, linear = TRUE)
littlewood.verall(t, linear = FALSE)
```

---

littlewood.verall.plot

Plotting the mean value function for the Littlewood-Verall model

---

Description

littlewood.verall.plot plots the mean value function for the Littlewood-Verall model and the raw data into one window.

Usage

```
littlewood.verall.plot(theta0, theta1, rho, t, linear = T, xlab = "time",
    ylab = "Cumulated failures and estimated mean value function",
    main = NULL)
```

Arguments

theta0	parameter value for theta0
theta1	parameter value for theta1
rho	parameter value for rho
t	time between failure data
linear	logical. Should the linear or the quadratic form of the mean value function for the Littlewood-Verrall model be used of computation? If TRUE, which is the default, the linear form of the mean value function is used.
xlab	a title for the x axis
ylab	a title for the y axis
main	an overall title for the plot

Details

This function gives a plot of the mean value function for the Littlewood-Verall model. Here the estimated parameter values for `theta0`, `theta1` and `theta`, which are obtained by using `littlewood.verall`, can be put in. Internally the functions `mvf.ver.lin` or `mvf.ver.quad` are used to get the mean value function for the Littlewood-Verall model. This depends on the calibration, if the linear or the quadratic form of the mean value function for the Littlewood-Verall model should be used.

Value

A graph of the mean value function for the Littlewood-Verall model and of the raw data.

Author(s)

Andreas Wittmann <andreas_wittmann@gmx.de>

References

J.D. Musa, A. Iannino, and K. Okumoto. *Software Reliability: Measurement, Prediction, Application*. McGraw-Hill, 1987.

Michael R. Lyu. *Handbook of Software Realibility Engineering*. IEEE Computer Society Press, 1996. http://www.cse.cuhk.edu.hk/~lyu/book/reliability/

See Also

`littlewood.verall`, `mvf.ver.lin`, `mvf.ver.quad`

Examples

```
# time between-failure-data from DACS Software Reliability Dataset
# homepage, see system code 1. Number of failures is 136.
t <- c(3, 30, 113, 81, 115, 9, 2, 20, 20, 15, 138, 50, 77, 24,
       108, 88, 670, 120, 26, 114, 325, 55, 242, 68, 422, 180,
       10, 1146, 600, 15, 36, 4, 0, 8, 227, 65, 176, 58, 457,
       300, 97, 263, 452, 255, 197, 193, 6, 79, 816, 1351, 148,
       21, 233, 134, 357, 193, 236, 31, 369, 748, 0, 232, 330,
       365, 1222, 543, 10, 16, 529, 379, 44, 129, 810, 290, 300,
       529, 281, 160, 828, 1011, 445, 296, 1755, 1064, 1783,
       860, 983, 707, 33, 868, 724, 2323, 2930, 1461, 843, 12,
       261, 1800, 865, 1435, 30, 143, 108, 0, 3110, 1247, 943,
       700, 875, 245, 729, 1897, 447, 386, 446, 122, 990, 948,
       1082, 22, 75, 482, 5509, 100, 10, 1071, 371, 790, 6150,
       3321, 1045, 648, 5485, 1160, 1864, 4116)

theta0 <- littlewood.verall(t, linear = TRUE)$theta0
theta1 <- littlewood.verall(t, linear = TRUE)$theta1
rho <- littlewood.verall(t, linear = TRUE)$rho
littlewood.verall.plot(theta0, theta1, rho, t, linear = TRUE,
  xlab = "time (in seconds)", main = "Littlewood-Verall model (linear)")

## Not run:
## theta0 <- littlewood.verall(t, linear = FALSE)$theta0
```

```
## theta1 <- littlewood.verall(t, linear = FALSE)$theta1
## rho <- littlewood.verall(t, linear = FALSE)$rho
## littlewood.verall.plot(theta0, theta1, rho, t, linear = FALSE,
##   xlab = "time (in seconds)", main = "Littlewood-Verall modell (quadratic)")
## End(Not run)
```

`moranda.geometric` *Maximum Likelihood estimation of mean value function for Moranda-Geometric model*

Description

`moranda.geometric` computes the Maximum Likelihood estimates for the parameters `D` and `theta` of the mean value function for the Moranda-Geometric model.

Usage

```
moranda.geometric(t, init = c(0, 1), tol = .Machine$double.eps^0.25)
```

Arguments

`t`	time between failure data
`init`	initial values for Maximum Likelihood fit of the mean value function for the Moranda-Geometric model.
`tol`	the desired accuracy

Details

This function estimates the parameters `D` and `theta` of the mean value function for the Moranda-Geometric model. With Maximum Likelihood estimation one gets the following equation, which have to be minimized, to get `phi`. This is

$$\frac{\sum_{i=1}^{n} i\phi^i t_i}{\sum_{i=1}^{n} \phi^i t_i} - \frac{n+1}{2} = 0.$$

The solution of these is then put in in the following equation in order to get `D`

$$D = \frac{\phi n}{\sum_{i=1}^{n} \phi^i t_i}.$$

Where t is the time between failure data and n is the length or in other words the size of the time between failure data.

Value

A list containing following components:

`rho`	Maximum Likelihood estimate for `rho`
`theta`	Maximum Likelihood estimate for `theta`

Author(s)

Andreas Wittmann <andreas_wittmann@gmx.de>

References

J.D. Musa, A. Iannino, and K. Okumoto. *Software Reliability: Measurement, Prediction, Application*. McGraw-Hill, 1987.

Michael R. Lyu. *Handbook of Software Realibility Engineering*. IEEE Computer Society Press, 1996. http://www.cse.cuhk.edu.hk/~lyu/book/reliability/

See Also

moranda.geometric.plot, mvf.mor

Examples

```
# time between-failure-data from DACS Software Reliability Dataset
# homepage, see system code 1. Number of failures is 136.
t <- c(3, 30, 113, 81, 115, 9, 2, 20, 20, 15, 138, 50, 77, 24,
       108, 88, 670, 120, 26, 114, 325, 55, 242, 68, 422, 180,
       10, 1146, 600, 15, 36, 4, 0, 8, 227, 65, 176, 58, 457,
       300, 97, 263, 452, 255, 197, 193, 6, 79, 816, 1351, 148,
       21, 233, 134, 357, 193, 236, 31, 369, 748, 0, 232, 330,
       365, 1222, 543, 10, 16, 529, 379, 44, 129, 810, 290, 300,
       529, 281, 160, 828, 1011, 445, 296, 1755, 1064, 1783,
       860, 983, 707, 33, 868, 724, 2323, 2930, 1461, 843, 12,
       261, 1800, 865, 1435, 30, 143, 108, 0, 3110, 1247, 943,
       700, 875, 245, 729, 1897, 447, 386, 446, 122, 990, 948,
       1082, 22, 75, 482, 5509, 100, 10, 1071, 371, 790, 6150,
       3321, 1045, 648, 5485, 1160, 1864, 4116)

moranda.geometric(t)
```

---

moranda.geometric.plot

Plotting the mean value function for the Moranda-Geometric model

---

Description

moranda.geometric.plot plots the mean value function for the Moranda-Geometric model and the raw data into one window.

Usage

```
moranda.geometric.plot(D, theta, t, xlab = "time",
    ylab = "Cumulated failures and estimated mean value function",
    main = NULL)
```

Arguments

D	parameter value for D
theta	parameter value for theta
t	time between failure data
xlab	a title for the x axis
ylab	a title for the y axis
main	an overall title for the plot

Details

This function gives a plot of the mean value function for the Moranda-Geometric model. Here the estimated values for D and theta, which are obtained by using moranda.geometric, can be put in. Internally the function mvf.mor is used to get the mean value function for the Moranda-Geometric model.

Value

A graph of the mean value function for the Moranda-Geometric model and of the raw data.

Author(s)

Andreas Wittmann <andreas_wittmann@gmx.de>

References

J.D. Musa, A. Iannino, and K. Okumoto. *Software Reliability: Measurement, Prediction, Application*. McGraw-Hill, 1987.

Michael R. Lyu. *Handbook of Software Realibility Engineering*. IEEE Computer Society Press, 1996. http://www.cse.cuhk.edu.hk/~lyu/book/reliability/

See Also

moranda.geometric, mvf.mor

Examples

```
# time between-failure-data from DACS Software Reliability Dataset
# homepage, see system code 1. Number of failures is 136.
t <- c(3, 30, 113, 81, 115, 9, 2, 20, 20, 15, 138, 50, 77, 24,
       108, 88, 670, 120, 26, 114, 325, 55, 242, 68, 422, 180,
       10, 1146, 600, 15, 36, 4, 0, 8, 227, 65, 176, 58, 457,
       300, 97, 263, 452, 255, 197, 193, 6, 79, 816, 1351, 148,
       21, 233, 134, 357, 193, 236, 31, 369, 748, 0, 232, 330,
       365, 1222, 543, 10, 16, 529, 379, 44, 129, 810, 290, 300,
       529, 281, 160, 828, 1011, 445, 296, 1755, 1064, 1783,
       860, 983, 707, 33, 868, 724, 2323, 2930, 1461, 843, 12,
       261, 1800, 865, 1435, 30, 143, 108, 0, 3110, 1247, 943,
       700, 875, 245, 729, 1897, 447, 386, 446, 122, 990, 948,
```

```
       1082, 22, 75, 482, 5509, 100, 10, 1071, 371, 790, 6150,
       3321, 1045, 648, 5485, 1160, 1864, 4116)

D <- moranda.geometric(t)$D
theta <- moranda.geometric(t)$theta

moranda.geometric.plot(D, theta, t, xlab = "time (in seconds)",
                       main = "Moranda-Geometric model")
```

`musa.okumoto` *Maximum Likelihood estimation of mean value function for Musa-Okumoto model*

Description

`musa.okumoto` computes the Maximum Likelihood estimates for the parameters `theta0` and `theta1` of the mean value function for the Musa-Okumoto model.

Usage

```
musa.okumoto(t, init = c(0, 1), tol = .Machine$double.eps^0.25)
```

Arguments

`t`	time between failure data
`init`	initial values for Maximum Likelihood fit of the mean value function for the Musa-Okumoto model.
`tol`	the desired accuracy

Details

This function estimates the parameters `theta0` and `theta1` of the mean value function for the Musa-Okumoto model. With Maximum Likelihood estimation one gets the following equation, which have to be minimized, to get `theta1`. This is

$$\frac{1}{\theta_1}\sum_{i=1}^{n}\frac{1}{1+\theta_1 t_i} - \frac{nt_n}{(1+\theta_1 t_n)\log(1+\theta_1 t_n)} = 0.$$

The solution of these is then put in in the following equation in order to get `theta0`

$$\theta_0 = \frac{n}{\log(1+\theta_1 t_n)}.$$

Where t is the time between failure data and n is the length or in other words the size of the time between failure data.

Value

A list containing following components:

`theta0`	Maximum Likelihood estimate for `theta0`
`theta1`	Maximum Likelihood estimate for `theta1`

Author(s)

Andreas Wittmann <andreas_wittmann@gmx.de>

References

J.D. Musa, A. Iannino, and K. Okumoto. *Software Reliability: Measurement, Prediction, Application*. McGraw-Hill, 1987.

Michael R. Lyu. *Handbook of Software Realibility Engineering*. IEEE Computer Society Press, 1996. http://www.cse.cuhk.edu.hk/~lyu/book/reliability/

See Also

`musa.okumoto.plot`, `mvf.musa`

Examples

```
# time between-failure-data from DACS Software Reliability Dataset
# homepage, see system code 1. Number of failures is 136.
t <- c(3, 30, 113, 81, 115, 9, 2, 20, 20, 15, 138, 50, 77, 24,
       108, 88, 670, 120, 26, 114, 325, 55, 242, 68, 422, 180,
       10, 1146, 600, 15, 36, 4, 0, 8, 227, 65, 176, 58, 457,
       300, 97, 263, 452, 255, 197, 193, 6, 79, 816, 1351, 148,
       21, 233, 134, 357, 193, 236, 31, 369, 748, 0, 232, 330,
       365, 1222, 543, 10, 16, 529, 379, 44, 129, 810, 290, 300,
       529, 281, 160, 828, 1011, 445, 296, 1755, 1064, 1783,
       860, 983, 707, 33, 868, 724, 2323, 2930, 1461, 843, 12,
       261, 1800, 865, 1435, 30, 143, 108, 0, 3110, 1247, 943,
       700, 875, 245, 729, 1897, 447, 386, 446, 122, 990, 948,
       1082, 22, 75, 482, 5509, 100, 10, 1071, 371, 790, 6150,
       3321, 1045, 648, 5485, 1160, 1864, 4116)

musa.okumoto(t)
```

---

musa.okumoto.plot *Plotting the mean value function for the Musa-Okumoto model*

Description

`musa.okumoto.plot` plots the estimated mean value function for the Musa-Okumoto model and the raw data into one window.

Usage

```
musa.okumoto.plot(theta0, theta1, t, xlab = "time",
    ylab = "Cumulated failures and estimated mean value function",
    main = NULL)
```

Arguments

theta0	parameter value for theta0
theta1	parameter value for theta1
t	time between failure data
xlab	a title for the x axis
ylab	a title for the y axis
main	an overall title for the plot

Details

This function gives a plot of the mean value function for the Musa-Okumoto model. Here the estimated parameter values for theta0 and theta1, which are obtained by using musa.okumoto, can be put in. Internally the function mvf.musa is used to get the mean value function for the Musa-Okumoto model.

Value

A graph of the mean value function for the Musa-Okumoto model and of the raw data.

Author(s)

Andreas Wittmann <andreas_wittmann@gmx.de>

References

J.D. Musa, A. Iannino, and K. Okumoto. *Software Reliability: Measurement, Prediction, Application*. McGraw-Hill, 1987.

Michael R. Lyu. *Handbook of Software Realibility Engineering*. IEEE Computer Society Press, 1996. http://www.cse.cuhk.edu.hk/~lyu/book/reliability/

See Also

musa.okumoto, mvf.musa

Examples

```
# time between-failure-data from DACS Software Reliability Dataset
# homepage, see system code 1. Number of failures is 136.
t <- c(3, 30, 113, 81, 115, 9, 2, 20, 20, 15, 138, 50, 77, 24,
       108, 88, 670, 120, 26, 114, 325, 55, 242, 68, 422, 180,
       10, 1146, 600, 15, 36, 4, 0, 8, 227, 65, 176, 58, 457,
       300, 97, 263, 452, 255, 197, 193, 6, 79, 816, 1351, 148,
```

```
        21, 233, 134, 357, 193, 236, 31, 369, 748, 0, 232, 330,
        365, 1222, 543, 10, 16, 529, 379, 44, 129, 810, 290, 300,
        529, 281, 160, 828, 1011, 445, 296, 1755, 1064, 1783,
        860, 983, 707, 33, 868, 724, 2323, 2930, 1461, 843, 12,
        261, 1800, 865, 1435, 30, 143, 108, 0, 3110, 1247, 943,
        700, 875, 245, 729, 1897, 447, 386, 446, 122, 990, 948,
        1082, 22, 75, 482, 5509, 100, 10, 1071, 371, 790, 6150,
        3321, 1045, 648, 5485, 1160, 1864, 4116)

theta0 <- musa.okumoto(t)$theta0
theta1 <- musa.okumoto(t)$theta1

musa.okumoto.plot(theta0, theta1, t, xlab = "time (in seconds)",
                  main = "Musa-Okumoto model")
```

`mvf.duane` *Mean value function for the Duane model*

Description

`mvf.duane` returns the mean value function for the Duane model.

Usage

```
mvf.duane(rho, theta, t)
```

Arguments

`rho`	parameter value for `rho`
`theta`	parameter value for `theta`
`t`	time between failure data

Details

This function gives the values of the mean value function for the Duane model, this is written as

$$\mu(t) = \rho t^{\theta}.$$

Further there is a verifying if the parameters `rho` and `theta` satisfy the assumptions for the Duane model. So the paramters `rho` and `theta` have to be larger than zero, in equations $\rho > 0$ and $\theta > 0$.

Value

The mean value function for the Duane model.

Author(s)

Andreas Wittmann <andreas_wittmann@gmx.de>

References

J.D. Musa, A. Iannino, and K. Okumoto. *Software Reliability: Measurement, Prediction, Application*. McGraw-Hill, 1987.

Michael R. Lyu. *Handbook of Software Realibility Engineering*. IEEE Computer Society Press, 1996. http://www.cse.cuhk.edu.hk/~lyu/book/reliability/

See Also

duane, duane.plot

Examples

```
# time between-failure-data from DACS Software Reliability Dataset
# homepage, see system code 1. Number of failures is 136.
t <- c(3, 30, 113, 81, 115, 9, 2, 20, 20, 15, 138, 50, 77, 24,
       108, 88, 670, 120, 26, 114, 325, 55, 242, 68, 422, 180,
       10, 1146, 600, 15, 36, 4, 0, 8, 227, 65, 176, 58, 457,
       300, 97, 263, 452, 255, 197, 193, 6, 79, 816, 1351, 148,
       21, 233, 134, 357, 193, 236, 31, 369, 748, 0, 232, 330,
       365, 1222, 543, 10, 16, 529, 379, 44, 129, 810, 290, 300,
       529, 281, 160, 828, 1011, 445, 296, 1755, 1064, 1783,
       860, 983, 707, 33, 868, 724, 2323, 2930, 1461, 843, 12,
       261, 1800, 865, 1435, 30, 143, 108, 0, 3110, 1247, 943,
       700, 875, 245, 729, 1897, 447, 386, 446, 122, 990, 948,
       1082, 22, 75, 482, 5509, 100, 10, 1071, 371, 790, 6150,
       3321, 1045, 648, 5485, 1160, 1864, 4116)

duane.par1 <- duane(t)$rho
duane.par2 <- duane(t)$theta

mvf.duane(duane.par1, duane.par2, t)
```

---

mvf.mor *Mean value function for the Moranda-Geometric model*

Description

mvf.mor returns the mean value function for the Moranda-Geometric model.

Usage

```
mvf.mor(D, theta, t)
```

Arguments

D	parameter value for D
theta	parameter value for theta
t	time between failure data

Details

This function gives the values of the mean value function for the Moranda-Geometric model, this is written as

$$\mu(t) = \frac{1}{\theta} \log\{[D\theta \exp(\theta)]t + 1\}.$$

Further there is a verifying if the parameter `theta` satisfy the assumptions of the Moranda-Geometric model. So the paramter `theta` have to be larger than zero, in equation $\theta > 0$.

Value

The mean value function for the Moranda-Geometric model.

Author(s)

Andreas Wittmann <andreas_wittmann@gmx.de>

References

J.D. Musa, A. Iannino, and K. Okumoto. *Software Reliability: Measurement, Prediction, Application*. McGraw-Hill, 1987.

Michael R. Lyu. *Handbook of Software Realibility Engineering*. IEEE Computer Society Press, 1996. http://www.cse.cuhk.edu.hk/~lyu/book/reliability/

See Also

moranda.geometric, moranda.geometric.plot

Examples

```
# time between-failure-data from DACS Software Reliability Dataset
# homepage, see system code 1. Number of failures is 136.
t <- c(3, 30, 113, 81, 115, 9, 2, 20, 20, 15, 138, 50, 77, 24,
       108, 88, 670, 120, 26, 114, 325, 55, 242, 68, 422, 180,
       10, 1146, 600, 15, 36, 4, 0, 8, 227, 65, 176, 58, 457,
       300, 97, 263, 452, 255, 197, 193, 6, 79, 816, 1351, 148,
       21, 233, 134, 357, 193, 236, 31, 369, 748, 0, 232, 330,
       365, 1222, 543, 10, 16, 529, 379, 44, 129, 810, 290, 300,
       529, 281, 160, 828, 1011, 445, 296, 1755, 1064, 1783,
       860, 983, 707, 33, 868, 724, 2323, 2930, 1461, 843, 12,
       261, 1800, 865, 1435, 30, 143, 108, 0, 3110, 1247, 943,
       700, 875, 245, 729, 1897, 447, 386, 446, 122, 990, 948,
       1082, 22, 75, 482, 5509, 100, 10, 1071, 371, 790, 6150,
       3321, 1045, 648, 5485, 1160, 1864, 4116)

mor.par1 <- moranda.geometric(t)$D
mor.par2 <- moranda.geometric(t)$theta

mvf.mor(mor.par1, mor.par2, t)
```

`mvf.musa` *Mean value function for the Musa-Okumoto model*

Description

`mvf.musa` returns the mean value function for the Musa-Okumoto model.

Usage

```
mvf.musa(theta0, theta1, t)
```

Arguments

`theta0`	parameter value for `theta0`
`theta1`	parameter value for `theta1`
`t`	time between failure data

Details

This function gives the values of the mean value function for the Musa-Okumoto model, this is written as

$$\mu(t) = \theta_0 \log(\theta_1 t + 1).$$

Value

The mean value function for the Musa-Okumoto model.

Author(s)

Andreas Wittmann <andreas_wittmann@gmx.de>

References

J.D. Musa, A. Iannino, and K. Okumoto. *Software Reliability: Measurement, Prediction, Application*. McGraw-Hill, 1987.

Michael R. Lyu. *Handbook of Software Realibility Engineering*. IEEE Computer Society Press, 1996. http://www.cse.cuhk.edu.hk/~lyu/book/reliability/

See Also

`musa.okumoto`, `musa.okumoto.plot`

Examples

```
# time between-failure-data from DACS Software Reliability Dataset
# homepage, see system code 1. Number of failures is 136.
t <- c(3, 30, 113, 81, 115, 9, 2, 20, 20, 15, 138, 50, 77, 24,
       108, 88, 670, 120, 26, 114, 325, 55, 242, 68, 422, 180,
       10, 1146, 600, 15, 36, 4, 0, 8, 227, 65, 176, 58, 457,
       300, 97, 263, 452, 255, 197, 193, 6, 79, 816, 1351, 148,
       21, 233, 134, 357, 193, 236, 31, 369, 748, 0, 232, 330,
       365, 1222, 543, 10, 16, 529, 379, 44, 129, 810, 290, 300,
       529, 281, 160, 828, 1011, 445, 296, 1755, 1064, 1783,
       860, 983, 707, 33, 868, 724, 2323, 2930, 1461, 843, 12,
       261, 1800, 865, 1435, 30, 143, 108, 0, 3110, 1247, 943,
       700, 875, 245, 729, 1897, 447, 386, 446, 122, 990, 948,
       1082, 22, 75, 482, 5509, 100, 10, 1071, 371, 790, 6150,
       3321, 1045, 648, 5485, 1160, 1864, 4116)

musa.par1 <- musa.okumoto(t)$theta0
musa.par2 <- musa.okumoto(t)$theta1

mvf.musa(musa.par1, musa.par2, t)
```

`mvf.ver.lin` *Mean value function in the linear form for the Littlewood-Verall model*

Description

`mvf.ver.lin` returns the mean value function in the linear form for the Littlewood-Verall model.

Usage

```
mvf.ver.lin(theta0, theta1, rho, t)
```

Arguments

`theta0`	parameter value for `theta0`
`theta1`	parameter value for `theta1`
`rho`	parameter value for `rho`
`t`	time between failure data

Details

This function gives the values of the mean value function in the linear form for the Littlewood-Verall model, this is written as

$$\mu(t) = \frac{1}{\theta_1}\sqrt{\theta_0^2 + 2\theta_1 t\rho}.$$

Further there is a verifying if the parameter `theta1` satisfy the assumptions for the Littlewood-Verall model. So the paramter `theta1` should not be equal zero, in equation $\theta_1 \neq 0$.

Value

The mean value function in the linear form for the Littlewood-Verall model.

Author(s)

Andreas Wittmann <andreas_wittmann@gmx.de>

References

J.D. Musa, A. Iannino, and K. Okumoto. *Software Reliability: Measurement, Prediction, Application*. McGraw-Hill, 1987.

Michael R. Lyu. *Handbook of Software Realibility Engineering*. IEEE Computer Society Press, 1996. http://www.cse.cuhk.edu.hk/~lyu/book/reliability/

See Also

littlewood.verall, littlewood.verall.plot, mvf.ver.quad

Examples

```
# time between-failure-data from DACS Software Reliability Dataset
# homepage, see system code 1. Number of failures is 136.
t <- c(3, 30, 113, 81, 115, 9, 2, 20, 20, 15, 138, 50, 77, 24,
       108, 88, 670, 120, 26, 114, 325, 55, 242, 68, 422, 180,
       10, 1146, 600, 15, 36, 4, 0, 8, 227, 65, 176, 58, 457,
       300, 97, 263, 452, 255, 197, 193, 6, 79, 816, 1351, 148,
       21, 233, 134, 357, 193, 236, 31, 369, 748, 0, 232, 330,
       365, 1222, 543, 10, 16, 529, 379, 44, 129, 810, 290, 300,
       529, 281, 160, 828, 1011, 445, 296, 1755, 1064, 1783,
       860, 983, 707, 33, 868, 724, 2323, 2930, 1461, 843, 12,
       261, 1800, 865, 1435, 30, 143, 108, 0, 3110, 1247, 943,
       700, 875, 245, 729, 1897, 447, 386, 446, 122, 990, 948,
       1082, 22, 75, 482, 5509, 100, 10, 1071, 371, 790, 6150,
       3321, 1045, 648, 5485, 1160, 1864, 4116)

lit.par1 <- littlewood.verall(t, linear = TRUE)$theta0
lit.par2 <- littlewood.verall(t, linear = TRUE)$theta1
lit.par3 <- littlewood.verall(t, linear = TRUE)$rho

mvf.ver.lin(lit.par1, lit.par2, lit.par3, t)
```

---

mvf.ver.quad *Mean value function in the quadratic form for the Littlewood-Verall model*

Description

mvf.ver.quad returns mean value function in the quadratic form for the Littlewood-Verall model.

Usage

```
mvf.ver.quad(theta0, theta1, rho, t)
```

Arguments

theta0	parameter value for theta0
theta1	parameter value for theta1
rho	parameter value for rho
t	time between failure data

Details

This function gives the values of the mean value function in the quadratic form for the Littlewood-Verall model, this is written as

$$\mu(t) = 3v_1(Q_1 + Q_2),$$

where

$$v_1 = \frac{(\rho - 1)^{1/3}}{(18\theta_1)^{1/3}},$$

$$v_2 = \frac{4\theta_0^3}{9(\rho - 1)^2\theta_1},$$

$$Q_1 = [t + (t^2 + v_2)^{1/2}]^{1/3}$$

and

$$Q_2 = [t - (t^2 + v_2)^{1/2}]^{1/3}.$$

Further there is a verifying if the parameter theta1 satisfy the assumptions for the Littlewood-Verall model. So the paramter theta1 should net be equal zero, in equation $\theta_1 \neq 0$.

Value

The mean value function in the quadratic form for the Littlewood-Verall model.

Author(s)

Andreas Wittmann <andreas_wittmann@gmx.de>

References

J.D. Musa, A. Iannino, and K. Okumoto. *Software Reliability: Measurement, Prediction, Application*. McGraw-Hill, 1987.

Michael R. Lyu. *Handbook of Software Realibility Engineering*. IEEE Computer Society Press, 1996. http://www.cse.cuhk.edu.hk/~lyu/book/reliability/

See Also

littlewood.verall, littlewood.verall.plot, mvf.ver.lin

Examples

```
# time between-failure-data from DACS Software Reliability Dataset
# homepage, see system code 1. Number of failures is 136.
t <- c(3, 30, 113, 81, 115, 9, 2, 20, 20, 15, 138, 50, 77, 24,
       108, 88, 670, 120, 26, 114, 325, 55, 242, 68, 422, 180,
       10, 1146, 600, 15, 36, 4, 0, 8, 227, 65, 176, 58, 457,
       300, 97, 263, 452, 255, 197, 193, 6, 79, 816, 1351, 148,
       21, 233, 134, 357, 193, 236, 31, 369, 748, 0, 232, 330,
       365, 1222, 543, 10, 16, 529, 379, 44, 129, 810, 290, 300,
       529, 281, 160, 828, 1011, 445, 296, 1755, 1064, 1783,
       860, 983, 707, 33, 868, 724, 2323, 2930, 1461, 843, 12,
       261, 1800, 865, 1435, 30, 143, 108, 0, 3110, 1247, 943,
       700, 875, 245, 729, 1897, 447, 386, 446, 122, 990, 948,
       1082, 22, 75, 482, 5509, 100, 10, 1071, 371, 790, 6150,
       3321, 1045, 648, 5485, 1160, 1864, 4116)

lit.par1 <- littlewood.verall(t, linear = TRUE)$theta0
lit.par2 <- littlewood.verall(t, linear = TRUE)$theta1
lit.par3 <- littlewood.verall(t, linear = TRUE)$rho

mvf.ver.quad(lit.par1, lit.par2, lit.par3, t)
```

`rel.plot` *Plotting the relative error for the mean value functions for all models*

Description

`total.plot` plots the relative error for the the mean value function for all models into one window.

Usage

```
rel.plot(duane.par1, duane.par2, lit.par1, lit.par2, lit.par3, mor.par1,
         mor.par2, musa.par1, musa.par2, t, linear = T, ymin, ymax,
         xlab = "time", ylab = "relative error", main = NULL)
```

Arguments

`duane.par1`	parameter value for `rho` for Duane model
`duane.par2`	parameter value for `theta` for Duane model
`lit.par1`	parameter value for `theta0` for Littlewood-Verall model
`lit.par2`	parameter value for `theta1` for Littlewood-Verall model
`lit.par3`	parameter value for `rho` for Littlewood-Verall model
`mor.par1`	parameter value for `D` for Moranda-Geometric model
`mor.par2`	parameter value for `theta` for Moranda-Geometric model
`musa.par1`	parameter value for `theta0` for Musa-Okumoto model
`musa.par2`	parameter value for `theta1` for Musa-Okumoto model

t	time between failure data
linear	logical. Should the linear or the quadratic form of the mean value function for the Littlewood-Verrall model be used of computation? If TRUE, which is the default, the linear form of the mean value function is used.
ymin	the minimal y limit of the plot
ymax	the maximal y limit of the plot
xlab	a title for the x axis
ylab	a title for the y axis
main	an overall title for the plot

Details

This function gives a plot of the relative error for the mean value functions for all models, this is

$$\text{relative error} = \frac{\mu(t_i) - i}{i}, i = 1, 2, ...,$$

where $\mu(t)$ is a mean value function and i is the number of failures. Here the estimated parameter values, which are obtained by using duane, littlewood.verall, moranda.geometric und musa.okumoto can be put in. Internally the functions mvf.duane, mvf.ver.lin, mvf.ver.quad, mvf.mor and mvf.musa are used to get the mean value functions for all models.

Value

A graph of the relative error for the mean value functions for all models.

Author(s)

Andreas Wittmann <andreas_wittmann@gmx.de>

References

J.D. Musa, A. Iannino, and K. Okumoto. *Software Reliability: Measurement, Prediction, Application*. McGraw-Hill, 1987.

Michael R. Lyu. *Handbook of Software Realibility Engineering*. IEEE Computer Society Press, 1996. http://www.cse.cuhk.edu.hk/~lyu/book/reliability/

See Also

duane.plot, littlewood.verall.plot, moranda.geometric.plot, musa.okumoto.plot, total.plot

Examples

```
# time between-failure-data from DACS Software Reliability Dataset
# homepage, see system code 1. Number of failures is 136.
t <- c(3, 30, 113, 81, 115, 9, 2, 20, 20, 15, 138, 50, 77, 24,
       108, 88, 670, 120, 26, 114, 325, 55, 242, 68, 422, 180,
       10, 1146, 600, 15, 36, 4, 0, 8, 227, 65, 176, 58, 457,
       300, 97, 263, 452, 255, 197, 193, 6, 79, 816, 1351, 148,
```

```
        21, 233, 134, 357, 193, 236, 31, 369, 748, 0, 232, 330,
        365, 1222, 543, 10, 16, 529, 379, 44, 129, 810, 290, 300,
        529, 281, 160, 828, 1011, 445, 296, 1755, 1064, 1783,
        860, 983, 707, 33, 868, 724, 2323, 2930, 1461, 843, 12,
        261, 1800, 865, 1435, 30, 143, 108, 0, 3110, 1247, 943,
        700, 875, 245, 729, 1897, 447, 386, 446, 122, 990, 948,
        1082, 22, 75, 482, 5509, 100, 10, 1071, 371, 790, 6150,
        3321, 1045, 648, 5485, 1160, 1864, 4116)

duane.par1 <- duane(t)$rho
duane.par2 <- duane(t)$theta

lit.par1 <- littlewood.verall(t, linear = TRUE)$theta0
lit.par2 <- littlewood.verall(t, linear = TRUE)$theta1
lit.par3 <- littlewood.verall(t, linear = TRUE)$rho

mor.par1 <- moranda.geometric(t)$D
mor.par2 <- moranda.geometric(t)$theta

musa.par1 <- musa.okumoto(t)$theta0
musa.par2 <- musa.okumoto(t)$theta1

rel.plot(duane.par1, duane.par2, lit.par1, lit.par2, lit.par3, mor.par1,
         mor.par2, musa.par1, musa.par2, t, linear = TRUE, ymin = -1,
         ymax = 2.5, xlab = "time (in seconds)", main = "relative error")

## Not run:
## rel.plot(duane.par1, duane.par2, lit.par1, lit.par2, lit.par3, mor.par1,
##          mor.par2, musa.par1, musa.par2, t, linear = TRUE,
##          xlab = "time (in seconds)", main = "relative error")
## End(Not run)
```

`total.plot` *Plotting the mean value functions for all models*

Description

`total.plot` plots the mean value function for all models and the raw data into one window.

Usage

```
total.plot(duane.par1, duane.par2, lit.par1, lit.par2, lit.par3, mor.par1,
           mor.par2, musa.par1, musa.par2, t, linear = T, xlab = "time",
           ylab = "Cumulated failures and estimated mean value functions",
           main = NULL)
```

Arguments

`duane.par1`	parameter value for `rho` for Duane model

duane.par2	parameter value for theta for Duane model
lit.par1	parameter value for theta0 for Littlewood-Verall model
lit.par2	parameter value for theta1 for Littlewood-Verall model
lit.par3	parameter value for rho for Littlewood-Verall model
mor.par1	parameter value for D for Moranda-Geometric model
mor.par2	parameter value for theta for Moranda-Geometric model
musa.par1	parameter value for theta0 for Musa-Okumoto model
musa.par2	parameter value for theta1 for Musa-Okumoto model
t	time between failure data
linear	logical. Should the linear or the quadratic form of the mean value function for the Littlewood-Verrall model be used of computation? If TRUE, which is the default, the linear form of the mean value function is used.
xlab	a title for the x axis
ylab	a title for the y axis
main	an overall title for the plot

Details

This function gives a plot of the mean value functions for all models. Here the estimated parameter values, which are obtained by using duane, littlewood.verall, moranda.geometric und musa.okumoto can be put in. Internally the functions mvf.duane, mvf.ver.lin, mvf.ver.quad, mvf.mor and mvf.musa are used to get the mean value functions for all models.

Value

A graph of the mean value functions for all models and of the raw data.

Author(s)

Andreas Wittmann <andreas_wittmann@gmx.de>

References

J.D. Musa, A. Iannino, and K. Okumoto. *Software Reliability: Measurement, Prediction, Application*. McGraw-Hill, 1987.

Michael R. Lyu. *Handbook of Software Realibility Engineering*. IEEE Computer Society Press, 1996. http://www.cse.cuhk.edu.hk/~lyu/book/reliability/

See Also

duane.plot, littlewood.verall.plot, moranda.geometric.plot, musa.okumoto.plot

Examples

```
# time between-failure-data from DACS Software Reliability Dataset
# homepage, see system code 1. Number of failures is 136.
t <- c(3, 30, 113, 81, 115, 9, 2, 20, 20, 15, 138, 50, 77, 24,
       108, 88, 670, 120, 26, 114, 325, 55, 242, 68, 422, 180,
       10, 1146, 600, 15, 36, 4, 0, 8, 227, 65, 176, 58, 457,
       300, 97, 263, 452, 255, 197, 193, 6, 79, 816, 1351, 148,
       21, 233, 134, 357, 193, 236, 31, 369, 748, 0, 232, 330,
       365, 1222, 543, 10, 16, 529, 379, 44, 129, 810, 290, 300,
       529, 281, 160, 828, 1011, 445, 296, 1755, 1064, 1783,
       860, 983, 707, 33, 868, 724, 2323, 2930, 1461, 843, 12,
       261, 1800, 865, 1435, 30, 143, 108, 0, 3110, 1247, 943,
       700, 875, 245, 729, 1897, 447, 386, 446, 122, 990, 948,
       1082, 22, 75, 482, 5509, 100, 10, 1071, 371, 790, 6150,
       3321, 1045, 648, 5485, 1160, 1864, 4116)

duane.par1 <- duane(t)$rho
duane.par2 <- duane(t)$theta

lit.par1 <- littlewood.verall(t, linear = TRUE)$theta0
lit.par2 <- littlewood.verall(t, linear = TRUE)$theta1
lit.par3 <- littlewood.verall(t, linear = TRUE)$rho

mor.par1 <- moranda.geometric(t)$D
mor.par2 <- moranda.geometric(t)$theta

musa.par1 <- musa.okumoto(t)$theta0
musa.par2 <- musa.okumoto(t)$theta1

total.plot(duane.par1, duane.par2, lit.par1, lit.par2, lit.par3, mor.par1,
           mor.par2, musa.par1, musa.par2, t, linear = TRUE,
           xlab = "time (in seconds)", main = "all models")
```

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