

Package ‘MultiStepSSAD’

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Title Multiple-Steps Step-Stress Accelerated Degradation Modeling

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Description Implements statistical methods for multiple-steps step-stress accelerated degradation testing (SSADT) based on Wiener processes and Gamma processes as described by Pan and Balakrishnan (2010) <[doi:10.1080/03610918.2010.496060](https://doi.org/10.1080/03610918.2010.496060)>. Features maximum likelihood estimation (MLE), Bayesian Markov chain Monte Carlo (MCMC) sampling, Geweke convergence diagnostics, and reliability predictions under normal operating stress conditions.

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gamma_arrhenius	<i>Gamma-Arrhenius Step-Stress Accelerated Degradation Data</i>
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Description

Simulated degradation dataset generated using a Gamma process with an Arrhenius acceleration model under a 3-step step-stress accelerated degradation test (SSADT). Originally published in Table 4 of Pan and Balakrishnan (2010).

Usage

```
data(gamma_arrhenius)
```

Format

- A data frame with 30 rows and 6 variables:
- time** Inspection time in hours (72 to 2160 hours).
 - unit1** Degradation measurements for test unit 1.
 - unit2** Degradation measurements for test unit 2.
 - unit3** Degradation measurements for test unit 3.
 - unit4** Degradation measurements for test unit 4.
 - unit5** Degradation measurements for test unit 5.

Source

Pan, Z., & Balakrishnan, N. (2010). Multiple-Steps Step-Stress Accelerated Degradation Modeling Based on Wiener and Gamma Processes. *Communications in Statistics - Simulation and Computation*, 39(7), 1384-1402. doi:[10.1080/03610918.2010.496060](https://doi.org/10.1080/03610918.2010.496060)

Examples

```
data(gamma_arrhenius)
head(gamma_arrhenius)
```

gamma_power

Gamma-Power Step-Stress Accelerated Degradation Data

Description

Simulated degradation dataset generated using a Gamma process with a Power acceleration model under a 3-step step-stress accelerated degradation test (SSADT). Originally published in Table 5 of Pan and Balakrishnan (2010).

Usage

```
data(gamma_power)
```

Format

A data frame with 30 rows and 6 variables:

time Inspection time in hours (72 to 2160 hours).

unit1 Degradation measurements for test unit 1.

unit2 Degradation measurements for test unit 2.

unit3 Degradation measurements for test unit 3.

unit4 Degradation measurements for test unit 4.

unit5 Degradation measurements for test unit 5.

Source

Pan, Z., & Balakrishnan, N. (2010). Multiple-Steps Step-Stress Accelerated Degradation Modeling Based on Wiener and Gamma Processes. *Communications in Statistics - Simulation and Computation*, 39(7), 1384-1402. doi:[10.1080/03610918.2010.496060](https://doi.org/10.1080/03610918.2010.496060)

Examples

```
data(gamma_power)
head(gamma_power)
```

geweke_diag

Geweke's MCMC Convergence Diagnostic

Description

Computes Geweke's convergence diagnostic for MCMC chains by comparing the sample means of early and late parts of the Markov chain.

Usage

```
geweke_diag(chain, frac1 = 0.1, frac2 = 0.5)
```

Arguments

chain	A numeric matrix or data frame where columns correspond to parameters and rows to iterations, or a numeric vector for a single parameter.
frac1	Fraction of the chain to take from the beginning (default: 0.1).
frac2	Fraction of the chain to take from the end (default: 0.5).

Details

Geweke's convergence diagnostic tests for equality of the mean of early simulations (default first 10%) and the mean of later iterations (default last 50%). Under the null hypothesis of convergence, the test statistic follows a standard normal distribution.

Value

A data frame containing:

parameter	Name of the parameter.
mean_first	Mean of the initial fraction of iterations.
mean_last	Mean of the final fraction of iterations.
z_score	Geweke z-statistic.
p_value	Two-sided p-value for equality of means.
converged	Logical indicating whether convergence is supported at alpha = 0.05 level.

References

Geweke, J. (1992). Evaluating the accuracy of sampling-based approaches to the calculation of posterior moments. *Bayesian Statistics*, 4, 169-193.

Pan, Z., & Balakrishnan, N. (2010). Multiple-Steps Step-Stress Accelerated Degradation Modeling Based on Wiener and Gamma Processes. *Communications in Statistics - Simulation and Computation*, 39(7), 1384-1402. doi:[10.1080/03610918.2010.496060](https://doi.org/10.1080/03610918.2010.496060)

Examples

```
set.seed(123)
sample_chain <- matrix(rnorm(1000), ncol = 2, dimnames = list(NULL, c("param1", "param2")))
diag_res <- geweke_diag(sample_chain)
print(diag_res)
```

plot.ssadfit

*Plot Diagnostics and Degradation Paths for SSADT Models***Description**

Generates diagnostic plots for a fitted step-stress degradation model, including observed vs. fitted degradation paths and MCMC trace/posterior density plots (if fitted via MCMC).

Usage

```
## S3 method for class 'ssadfit'
plot(x, ...)
```

Arguments

`x` An object of class "ssadfit".
`...` Additional graphical parameters.

Value

Invisibly returns the input object `x`. Side effect: displays diagnostic plots.

Examples

```
data(wiener_arrhenius)
fit <- ssad_fit(wiener_arrhenius, process = "wiener", model = "arrhenius", method = "mle")
plot(fit)
```

predict.ssadfit

*Predict Lifetime Distribution and Reliability for SSADT Fit***Description**

Predicts the reliability function $R(t)$, cumulative failure distribution $F(t)$, and MTTF at normal operating stress conditions S_0 based on a fitted "ssadfit" model.

Usage

```
## S3 method for class 'ssadfit'
predict(object, t = seq(100, 10000, by = 100), S0 = 25, omega_F = 200, ...)
```

Arguments

object	An object of class "ssadfit".
t	Numeric vector of time points for reliability evaluation (default: seq(100, 10000, by = 100)).
S0	Normal use-stress level (default: 25).
omega_F	Failure threshold for degradation (default: 200).
...	Additional prediction arguments.

Value

An object of class "ssad_reliability" containing time, reliability $R(t)$, failure CDF $F(t)$, and MTTF.

Examples

```
data(wiener_arrhenius)
fit <- ssad_fit(wiener_arrhenius, process = "wiener", model = "arrhenius", method = "mle")
pred <- predict(fit, t = seq(100, 5000, by = 100), S0 = 25, omega_F = 200)
print(pred$mttf)
```

print.ssadfit	<i>Print Method for Step-Stress Accelerated Degradation Fit</i>
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Description

Prints a concise summary of the fitted step-stress accelerated degradation model.

Usage

```
## S3 method for class 'ssadfit'
print(x, ...)
```

Arguments

x	An object of class "ssadfit".
...	Additional arguments passed to print.

Value

Invisibly returns the input object x.

Examples

```
data(wiener_arrhenius)
fit <- ssad_fit(wiener_arrhenius, process = "wiener", model = "arrhenius", method = "mle")
print(fit)
```

Description

Master fitting function for step-stress accelerated degradation testing (SSADT) models using Wiener process or Gamma process degradation models with Arrhenius or Power acceleration relationships.

Usage

```
ssad_fit(
  data,
  process = c("wiener", "gamma"),
  model = c("arrhenius", "power"),
  stress_levels = c(45, 65, 85),
  thresholds = c(90, 160),
  method = c("mle", "mcmc"),
  init = NULL,
  n_iter = 5000,
  burnin = 1000,
  thin = 1
)
```

Arguments

data	A data frame containing inspection times in the first column and unit degradation measurements in subsequent columns, or long-format data with columns unit, time, degradation.
process	Character string specifying degradation process model: "wiener" or "gamma".
model	Acceleration model: "arrhenius" or "power".
stress_levels	Vector of stress levels $S = (S_1, S_2, \dots, S_K)$. Default: <code>c(45, 65, 85)</code> .
thresholds	Vector of degradation thresholds ($\omega_{a1}, \dots, \omega_{aK-1}$) at which stress levels are elevated. Default: <code>c(90, 160)</code> .
method	Estimation method: "mle" or "mcmc". Default: "mle".
init	Initial parameter vector.
n_iter	Number of MCMC iterations (default: 5000).
burnin	Number of burn-in iterations (default: 1000).
thin	Thinning interval for MCMC (default: 1).

Value

An S3 object of class "ssadfit" containing model fit results, parameter estimates, log-likelihood, and diagnostics.

References

Pan, Z., & Balakrishnan, N. (2010). Multiple-Steps Step-Stress Accelerated Degradation Modeling Based on Wiener and Gamma Processes. *Communications in Statistics - Simulation and Computation*, 39(7), 1384-1402. doi:[10.1080/03610918.2010.496060](https://doi.org/10.1080/03610918.2010.496060)

Examples

```
data(wiener_arrhenius)
fit <- ssad_fit(
  data = wiener_arrhenius,
  process = "wiener",
  model = "arrhenius",
  stress_levels = c(45, 65, 85),
  thresholds = c(90, 160),
  method = "mle"
)
print(fit)
summary(fit)
```

ssad_gamma

Gamma Process Step-Stress Accelerated Degradation Model Estimation

Description

Fits a Gamma process step-stress accelerated degradation model using Maximum Likelihood Estimation (MLE) or Bayesian Markov Chain Monte Carlo (MCMC) based on the Birnbaum-Saunders approximation for stress elevation times as described in Pan and Balakrishnan (2010).

Usage

```
ssad_gamma(
  data,
  stress_levels = c(45, 65, 85),
  thresholds = c(90, 160),
  model = c("arrhenius", "power"),
  method = c("mle", "mcmc"),
  init = NULL,
  n_iter = 5000,
  burnin = 1000,
  thin = 1
)
```

Arguments

data	A data frame containing inspection times in the first column and unit degradation measurements in subsequent columns, or a long-format data frame with columns unit, time, degradation.
------	---

stress_levels	Vector of stress levels $S = (S_1, S_2, \dots, S_K)$.
thresholds	Vector of degradation thresholds ($\omega_1, \dots, \omega_{K-1}$) at which stress levels are elevated.
model	Acceleration model: "arrhenius" or "power".
method	Estimation method: "mle" or "mcmc".
init	Initial parameter values $c(a, b, u)$.
n_iter	Number of MCMC iterations (default: 5000).
burnin	Number of burn-in iterations (default: 1000).
thin	Thinning interval for MCMC (default: 1).

Value

An object of class "ssadfit" containing fit results, parameter estimates, log-likelihood, MCMC samples (if applicable), and metadata.

References

Pan, Z., & Balakrishnan, N. (2010). Multiple-Steps Step-Stress Accelerated Degradation Modeling Based on Wiener and Gamma Processes. *Communications in Statistics - Simulation and Computation*, 39(7), 1384-1402. doi:[10.1080/03610918.2010.496060](https://doi.org/10.1080/03610918.2010.496060)

Examples

```
data(gamma_arrhenius)
fit_g <- ssad_gamma(
  data = gamma_arrhenius,
  stress_levels = c(45, 65, 85),
  thresholds = c(90, 160),
  model = "arrhenius",
  method = "mle"
)
print(fit_g)
```

ssad_reliability

Reliability and Lifetime Analysis for Step-Stress Accelerated Degradation Models

Description

Computes the reliability function $R(t)$, cumulative failure distribution $F(t)$, and Mean Time To Failure (MTTF) at use stress level S_0 and failure threshold ω_F based on fitted Wiener or Gamma process SSADT parameters.

Usage

```
ssad_reliability(
  t,
  process = c("wiener", "gamma"),
  model = c("arrhenius", "power"),
  params,
  S0,
  omega_F
)
```

Arguments

t	Numeric vector of time points at which to evaluate reliability.
process	Character string specifying the process type: "wiener" or "gamma".
model	Character string or function for acceleration model ("arrhenius" or "power").
params	Vector of estimated model parameters: c(a, b, sigma) for Wiener, or c(a, b, u) for Gamma.
S0	Normal use-stress level.
omega_F	Failure threshold for degradation.

Value

A list of class "ssad_reliability" containing:

time	Vector of time points.
reliability	Vector of reliability values $R(t)$.
cdf	Vector of cumulative distribution function values $F(t)$.
mttf	Mean Time To Failure under use stress S_0 .
process	Degradation process type.
S0	Use stress level.
omega_F	Failure threshold.

References

Pan, Z., & Balakrishnan, N. (2010). Multiple-Steps Step-Stress Accelerated Degradation Modeling Based on Wiener and Gamma Processes. *Communications in Statistics - Simulation and Computation*, 39(7), 1384-1402. doi:[10.1080/03610918.2010.496060](https://doi.org/10.1080/03610918.2010.496060)

Examples

```
# Wiener-Arrhenius model example
rel_wiener <- ssad_reliability(
  t = seq(100, 10000, by = 100),
  process = "wiener",
  model = "arrhenius",
  params = c(a = 5.4188, b = -2564.3, sigma = 0.0894),
```

```

    S0 = 25,
    omega_F = 200
  )
  print(rel_wiener$mttf)

```

ssad_simulate

Simulate Step-Stress Accelerated Degradation Data

Description

Generates simulated degradation path data for N test units subject to a K-steps step-stress accelerated degradation test (SSADT) under Wiener or Gamma stochastic process models.

Usage

```

ssad_simulate(
  n_units = 5,
  times = seq(72, 2160, by = 72),
  stress_levels = c(45, 65, 85),
  thresholds = c(90, 160),
  process = c("wiener", "gamma"),
  model = c("arrhenius", "power"),
  params
)

```

Arguments

n_units	Number of test units (e.g. 5).
times	Vector of inspection time points (e.g. seq(72, 2160, by = 72)).
stress_levels	Vector of stress levels $S = (S_1, S_2, \dots, S_K)$.
thresholds	Vector of degradation thresholds ($\omega_1, \dots, \omega_{K-1}$) at which stress is elevated.
process	Character string specifying "wiener" or "gamma".
model	Acceleration model: "arrhenius" or "power".
params	Model parameters: c(a, b, sigma) for Wiener, or c(a, b, u) for Gamma.

Value

A data frame with columns time, unit1, unit2, ..., unitN.

References

Pan, Z., & Balakrishnan, N. (2010). Multiple-Steps Step-Stress Accelerated Degradation Modeling Based on Wiener and Gamma Processes. *Communications in Statistics - Simulation and Computation*, 39(7), 1384-1402. doi:[10.1080/03610918.2010.496060](https://doi.org/10.1080/03610918.2010.496060)

Examples

```
set.seed(42)
sim_data <- ssad_simulate(
  n_units = 5,
  times = seq(72, 2160, by = 72),
  stress_levels = c(45, 65, 85),
  thresholds = c(90, 160),
  process = "wiener",
  model = "arrhenius",
  params = c(a = 5.3669, b = -2546.7, sigma = 0.1)
)
head(sim_data)
```

ssad_wiener	<i>Wiener Process Step-Stress Accelerated Degradation Model Estimation</i>
-------------	--

Description

Fits a Wiener process step-stress accelerated degradation model using Maximum Likelihood Estimation (MLE) or Bayesian Markov Chain Monte Carlo (MCMC) as described in Pan and Balakrishnan (2010).

Usage

```
ssad_wiener(
  data,
  stress_levels = c(45, 65, 85),
  thresholds = c(90, 160),
  model = c("arrhenius", "power"),
  method = c("mle", "mcmc"),
  init = NULL,
  n_iter = 5000,
  burnin = 1000,
  thin = 1
)
```

Arguments

data	A data frame containing inspection times in the first column and unit degradation measurements in subsequent columns, or a long-format data frame with columns unit, time, degradation.
stress_levels	Vector of stress levels $S = (S_1, S_2, \dots, S_K)$.
thresholds	Vector of degradation thresholds ($\omega_1, \dots, \omega_{K-1}$) at which stress levels are elevated.
model	Acceleration model: "arrhenius" or "power".
method	Estimation method: "mle" or "mcmc".

init	Initial parameter values $c(a, b, \sigma)$.
n_iter	Number of MCMC iterations (default: 10000).
burnin	Number of burn-in iterations (default: 2000).
thin	Thinning interval for MCMC (default: 1).

Value

An object of class "ssadfit" containing fit results, parameter estimates, log-likelihood, MCMC samples (if applicable), and metadata.

References

Pan, Z., & Balakrishnan, N. (2010). Multiple-Steps Step-Stress Accelerated Degradation Modeling Based on Wiener and Gamma Processes. *Communications in Statistics - Simulation and Computation*, 39(7), 1384-1402. doi:[10.1080/03610918.2010.496060](https://doi.org/10.1080/03610918.2010.496060)

Examples

```
data(wiener_arrhenius)
fit_w <- ssad_wiener(
  data = wiener_arrhenius,
  stress_levels = c(45, 65, 85),
  thresholds = c(90, 160),
  model = "arrhenius",
  method = "mle"
)
print(fit_w)
```

summary.ssadfit

*Summary Method for Step-Stress Accelerated Degradation Fit***Description**

Produces a detailed statistical summary of a fitted step-stress degradation model, including parameter estimates, standard errors / MCMC quantiles, information criteria (AIC, BIC), and MCMC convergence diagnostics (if fitted via MCMC).

Usage

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

Arguments

object	An object of class "ssadfit".
...	Additional arguments passed to summary.

Value

Invisibly returns the input object object.

Examples

```
data(wiener_arrhenius)
fit <- ssad_fit(wiener_arrhenius, process = "wiener", model = "arrhenius", method = "mle")
summary(fit)
```

wiener_arrhenius	<i>Wiener-Arrhenius Step-Stress Accelerated Degradation Data</i>
------------------	--

Description

Simulated degradation dataset generated using a Wiener process with an Arrhenius acceleration model under a 3-step step-stress accelerated degradation test (SSADT). Originally published in Table 2 of Pan and Balakrishnan (2010).

Usage

```
data(wiener_arrhenius)
```

Format

A data frame with 30 rows and 6 variables:

time Inspection time in hours (72 to 2160 hours).

unit1 Degradation measurements for test unit 1.

unit2 Degradation measurements for test unit 2.

unit3 Degradation measurements for test unit 3.

unit4 Degradation measurements for test unit 4.

unit5 Degradation measurements for test unit 5.

Source

Pan, Z., & Balakrishnan, N. (2010). Multiple-Steps Step-Stress Accelerated Degradation Modeling Based on Wiener and Gamma Processes. *Communications in Statistics - Simulation and Computation*, 39(7), 1384-1402. doi:[10.1080/03610918.2010.496060](https://doi.org/10.1080/03610918.2010.496060)

Examples

```
data(wiener_arrhenius)
head(wiener_arrhenius)
```

wiener_power

Wiener-Power Step-Stress Accelerated Degradation Data

Description

Simulated degradation dataset generated using a Wiener process with a Power acceleration model under a 3-step step-stress accelerated degradation test (SSADT). Originally published in Table 3 of Pan and Balakrishnan (2010).

Usage

```
data(wiener_power)
```

Format

A data frame with 30 rows and 6 variables:

time Inspection time in hours (72 to 2160 hours).

unit1 Degradation measurements for test unit 1.

unit2 Degradation measurements for test unit 2.

unit3 Degradation measurements for test unit 3.

unit4 Degradation measurements for test unit 4.

unit5 Degradation measurements for test unit 5.

Source

Pan, Z., & Balakrishnan, N. (2010). Multiple-Steps Step-Stress Accelerated Degradation Modeling Based on Wiener and Gamma Processes. *Communications in Statistics - Simulation and Computation*, 39(7), 1384-1402. doi:[10.1080/03610918.2010.496060](https://doi.org/10.1080/03610918.2010.496060)

Examples

```
data(wiener_power)
head(wiener_power)
```

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