

Package: minimaxALT (via r-universe)

June 8, 2026

Type Package

Title Generate Optimal Designs of Accelerated Life Test using
PSO-Based Algorithm

Version 1.0.2

Encoding UTF-8

License GPL (>= 3)

Description A computationally efficient solution for generating optimal experimental designs in Accelerated Life Testing (ALT). Leveraging a Particle Swarm Optimization (PSO)-based hybrid algorithm, the package identifies optimal test plans that minimize estimation variance under specified failure models and stress profiles. For more detailed, see Lee et al. (2025), Optimal Robust Strategies for Accelerated Life Tests and Fatigue Testing of Polymer Composite Materials, submitted to Annals of Applied Statistics, <https://imstat.org/journals-and-publications/annals-of-applied-statistics/annals-of-applied-statistics-next-issues/>, and Hoang (2025), Model-Robust Minimax Design of Accelerated Life Tests via PSO-based Hybrid Algorithm, Master' Thesis, Unpublished.

SystemRequirements GNU Scientific Library (GSL), OpenMP

Imports Rcpp (>= 1.0.11), RcppArmadillo (>= 14.0.0.1), RcppGSL (>= 0.3.13), ggplot2 (>= 3.0.0), parallel (>= 4.0.0), stats, graphics

Depends R (>= 4.0.0)

LinkingTo Rcpp (>= 1.0.11), RcppArmadillo (>= 14.0.0.1), RcppGSL (>= 0.3.13)

RoxygenNote 7.3.2

URL <https://github.com/hoanglinh171/minimaxALT>

BugReports <https://github.com/hoanglinh171/minimaxALT/issues>

Suggests knitr, rmarkdown, testthat (>= 3.0.0)

Config/testthat/edition 3

VignetteBuilder knitr

Config/pak/sysreqs libgsl0-dev

Repository https://hoanglinh171.r-universe.dev

Date/Publication 2025-10-10 13:40:05 UTC

RemoteUrl https://github.com/hoanglinh171/minimaxalt

RemoteRef HEAD

RemoteSha 1ad61e719fbd300c03e8798825e58775d684eb19

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check_equivalence_theorem
Check Equivalence Theorem for Optimal Design

Description

Evaluates whether a design satisfies the equivalence theorem.

Usage

```
check_equivalence_theorem(best_design, model_set, design_info, seed = 42)
```

Arguments

best_design	A matrix containing stress levels and allocated proportion of the design.
model_set	A matrix of models, including parameters and distribution, that maximize the optimality criteria with the given best particle's position.
design_info	A list containing design parameters such as factor levels, number of units, and other settings.
seed	Seed for reproducibility

Value

max_directional_derivative Maximum directional derivative within design space.

model_set The model set that is input.

model_weight The weight assigned to each model in the model set.

equivalence_data Generated designs and their corresponding directional derivative given the optimal design `best_particle`. Each design is a combination of factors with value in $[0, 1]$. These designs are data for plotting equivalence theorem plot.

References

1. Müller, C. H., & Pázman, A. (1998). Applications of necessary and sufficient conditions for maximin efficient designs. *Metrika*, 48, 1–19.
2. Huang, M.-N. L., & Lin, C.-S. (2006). Minimax and maximin efficient designs for estimating the location-shift parameter of parallel models with dual responses. *Journal of Multivariate Analysis*, 97(1), 198–210.

Examples

```
design_info <- set_design_info(k_levels=2, j_factor=1, n_unit=300,
                             censor_time=183, p=0.1, use_cond=0, sigma=0.6)

best_design <- rbind(
  c(0.682, 1),
  c(0.706, 0.294)
)

model_set <- rbind(
  c(0.01, 0.9, 1),
  c(0.01, 0.99, 2))

equi <- check_equivalence_theorem (best_design=best_design,
                                   model_set=model_set,
                                   design_info=design_info)

equi$max_directional_derivative
```

Description

Runs hybrid algorithm combining PSO and Nelder-Mead to find the optimal design of accelerated life test (ALT).

Usage

```

find_optimal_alt(
  design_type,
  distribution,
  design_info,
  pso_info,
  coef = NULL,
  coef_lower = NULL,
  coef_upper = NULL,
  init_values = NULL,
  highest_level = TRUE,
  n_threads = 1,
  verbose = TRUE,
  seed = 42
)

```

Arguments

design_type	Integer. 1: Locally optimal design, 2: Minimax design.
distribution	Integer. The assumed failure time distribution, 1: Weibull, 2: Log-normal, 3: Model robust (both distribution Weibull and Log-normal).
design_info	A list from 'set_design_info()' containing design specifications.
pso_info	A list from 'pso_setting()' defining PSO hyperparameters.
coef	Optional. Fixed model coefficients. Required if design_type = 1.
coef_lower	Optional. Lower bounds for model parameters. Required if design_type = 2.
coef_upper	Optional. Upper bounds for model parameters. Required if design_type = 2.
init_values	Optional. A list of initial values from 'initialize_values()'.
highest_level	Logical. Whether the highest stress level of the generated design is the upper bound of stress range x_h . Default value is TRUE.
n_threads	Integer. Number of threads for parallel processing.
verbose	Logical. If TRUE, print optimization progress.
seed	Integer. Seed for reproducibility

Value

- g_best** The global best design found by the hybrid algorithm.
- coef_best** The parameters corresponding to the global best design.
- distribution_best** The distribution corresponding to the global best design.
- max_directional_derivative** Maximum directional derivative within design space, evaluated using equivalence theorem.
- fg_best** The objective function value corresponding to the global best design.
- fg_best_hist** A vector tracking the best objective function value of each iteration.
- p_best** A matrix containing each particle's personal best design found during the optimization.

fp_best A vector containing the objective function values corresponding to each particle's personal best.

g_hist All particle positions of each iteration.

coef_best_hist The parameters corresponding to the global best designs of each iteration.

distribution_best_hist The distribution corresponding to the global best designs of each iteration.

model_set A matrix containing distribution and model parameters of global best particles of each iteration, duplicated models are removed.

model_weight The weight assigned to each model in the model set.

equivalence_data Generated designs and their corresponding directional derivative given the optimal design `g_best`. Each design is a combination of factors with value in $[0, 1]$. These designs are data for plotting equivalence theorem plot.

References

1. Chen P (2024). `_globpso: Particle Swarm Optimization Algorithms and Differential Evolution for Minimization Problems_`. R package version 1.2.1, <<https://github.com/PingYangChen/globpso>>.
2. Kennedy, J., & Eberhart, R. (1995). Particle swarm optimization. In Proceedings of the IEEE International Conference on Neural Networks (ICNN) (Vol. 4, pp. 1942–1948).
3. Lee, I. C., Chen, R. B., Wong, W. K., (in press). Optimal Robust Strategies for Accelerated Life Tests and Fatigue Testing of Polymer Composite Materials. *Annals of Applied Statistics*. <<https://imstat.org/journals-and-publications/annals-of-applied-statistics/annals-of-applied-statistics-next-issues/>>
4. Meeker, W. Q., & Escobar, L. A. (1998). *Statistical methods for reliability data*. New York: Wiley-Interscience.
5. Nelder, J. A. and Mead, R. (1965). A simplex algorithm for function minimization. *Computer Journal*, 7, 308–313. 10.1093/comjnl/7.4.308.

Examples

```
design_info <- set_design_info(k_levels=2, j_factor=1, n_unit=300,
                             censor_time=183, p=0.1, use_cond=0, sigma=0.6)

pso_info <- pso_setting(n_swarm=32, max_iter=128, early_stopping=10, tol=0.01)

set.seed(42)
res <- find_optimal_alt(design_type=1, distribution=1, design_info=design_info,
                       pso_info=pso_info, coef=c(0.001, 0.9), verbose = FALSE)

summary(res)
plot(res, x_l=0, x_h=1)
```


Description

Define hyperparameters for particle swarm optimization (PSO).

Usage

```
pso_setting(  
  n_swarm = 32,  
  max_iter = 128,  
  early_stopping = 10,  
  tol = 0.01,  
  c1 = 2.05,  
  c2 = 2.05,  
  w0 = 1.2,  
  w1 = 0.2,  
  w_var = 0.8,  
  vk = 4  
)
```

Arguments

n_swarm	Integer. Number of particles in the swarm.
max_iter	Integer. Maximum number of iterations.
early_stopping	Integer. The frequency, i.e. number of iterations, of validating the design optimality using equivalence theorem. The optimization process stops once maximum directional derivative is approximately 1.
tol	Numeric. Convergence tolerance. The algorithm stops if $\text{abs}(\text{max_directional_derivative} - 1) < \text{tol}$.
c1	Numeric. Cognitive acceleration coefficient. Default value is 2.05.
c2	Numeric. Social acceleration coefficient. Default value is 2.05.
w0	Numeric. Starting inertia weight. Default value is 1.2.
w1	Numeric. Ending inertia weight. Default value is 0.2.
w_var	Numeric. A number between $[0, 1]$ that controls the percentage of iterations during which PSO linearly decrease inertia weight from w_0 to w_1 . Default value is 0.8.
vk	Numeric. Velocity clamping factor. Default value is 4.

Value

A list of PSO hyperparameters.

Examples

```
pso_info <- pso_setting(n_swarm=32, max_iter=128, early_stopping=10, tol=0.01)
```

```
set_design_info      Set ALT Design Information
```

Description

Configures the settings for an accelerated life test.

Usage

```
set_design_info(  
  k_levels,  
  j_factor,  
  n_unit,  
  censor_time,  
  p,  
  use_cond,  
  sigma,  
  x_l = 0,  
  x_h = 1,  
  reparam = TRUE  
)
```

Arguments

k_levels	Integer. Number of stress levels.
j_factor	Integer. Number of stress factors.
n_unit	Integer. Total number of test units.
censor_time	Numeric. Test duration or censoring time.
p	Numeric. $0 < p < 1$. Lifetime percentile to be estimated at the use condition, i.e. stress levels are 0.
use_cond	Vector. Stress levels at the use condition.
sigma	Numeric. Scale parameter of the lifetime distribution.
x_l	Numeric. Lower bound of stress range. Default is 0.
x_h	Numeric. Upper bound of stress range. Default is 1.
reparam	Logical. Whether reparameterization is applied to model parameters. Reparameterization is supported for all design types, while non-reparameterization is only available for locally optimal design <code>design_type = 1</code> . Default is TRUE.

Value

A list of design specifications

Examples

```
design_info <- set_design_info(k_levels=3, j_factor=1, n_unit=300,  
                             censor_time=183, p=0.1, use_cond=c(0), sigma=0.6)
```

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