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Title Generalized Pivotal Quantity Inference for the Youden Index

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Description Monte Carlo simulation study of generalized pivotal quantity (GPQ) based confidence intervals for the Youden index and its optimal cut-point, following Lai, Tian and Schisterman (2012) <doi:10.1016/j.csda.2010.11.023>.

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BugReports https://github.com/jolmedilla/gpqyouden/issues

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Contents

calculate_mu1_for_dataframe 2
default_param_grid 3
dmixnorm 3
eq.J2 4

find_mu1_from_J_mixture 5
find_mu1_from_J2 6
generate_mixture_sample 6
generate_mixture_tables 7
generate_normal_tables 8
generate_param_grid 9
gpq_c 9
gpq_from_sample 10
gpq_J 11
gpq_mu 12
gpq_sigma 12
J_true_mixture 13
J2.theoretical 14
mix_sd 14
pmixnorm 15
run_one_row 16
run_parallel_grid 17
run_simulation 18

Index **20**

`calculate_mu1_for_dataframe`
Compute μ_1 for each row of a parameter data frame

Description

Convenience wrapper that applies `find_mu1_from_J2` row-wise to a data frame containing columns `mu2`, `var1`, `var2` and `J`.

Usage

```
calculate_mu1_for_dataframe(df)
```

Arguments

`df`	A data frame with columns `mu2`, `var1`, `var2` and `J`.

Value

A data frame with columns `mu1`, `original_J` and `theoretical_J`.

Examples

```
df <- data.frame(mu2 = 0, var1 = 1, var2 = 1, J = c(0.4, 0.6))
calculate_mu1_for_dataframe(df)
```

default_param_grid *Build the default parameter grid used in Lai et al. (2012)*

Description

Returns the full factorial combination of variances, Youden index values, and sample-size pairs used in the simulation study of Lai et al. (2012): $\sigma_1^2 \in \{0.5, 1, 3, 5\}$, $\sigma_2^2 = 1$, $\mu_2 = 0$, $J \in \{0.2, 0.4, 0.6, 0.8, 0.9\}$, and eight (n_1, n_2) pairs.

Usage

```
default_param_grid()
```

Value

A data frame with 160 rows and columns `mu2`, `sigma1`, `sigma2`, `J`, `n1`, `n2`, `var1`, `var2`.

See Also

`generate_param_grid`, `run_parallel_grid`

Examples

```
grid <- default_param_grid()
dim(grid)
head(grid)
```

dmixnorm *Density of the contaminated normal mixture*

Description

Density of the contaminated normal mixture

Usage

```
dmixnorm(x, mu, sigma, p = 0.1)
```

Arguments

`x`	Numeric vector. Points at which to evaluate the density.
`mu`	Numeric. Mean of the distribution.
`sigma`	Numeric. Base standard deviation.
`p`	Numeric. Contamination probability (default: 0.1).

Value

A numeric vector of density values.

See Also

pmixnorm, generate_mixture_sample

Examples

```
dmixnorm(x = seq(-3, 3, by = 1), mu = 0, sigma = 1, p = 0.1)
```

---

eq.J2 *Equation whose root gives μ_1*

Description

Auxiliary function used by find_mu1_from_J2: evaluates $J(\mu_1) - J_{\text{target}}$.

Usage

```
eq.J2(x, parameters, J2, model)
```

Arguments

x	Numeric. Candidate value of μ_1.
parameters	Numeric vector $(\mu_2, \sigma_2, \sigma_1)$.
J2	Numeric. Target Youden index value.
model	Character. Currently only "norm" is supported.

Value

A numeric scalar.

Examples

```
# parameters = (mu2, sigma2, sigma1)
eq.J2(x = 1.68, parameters = c(0, 1, 1), J2 = 0.6, model = "norm")
```

`find_mu1_from_J_mixture` *Find μ_1 from the Youden index under the mixture model*

Description

Numerically solves for μ_1 such that the true Youden index of two contaminated normal mixture distributions equals `J_target`.

Usage

```
find_mu1_from_J_mixture(
  J_target,
  mu2,
  sigma1,
  sigma2,
  p = 0.1,
  tol = 1e-06,
  max_expand = 60
)
```

Arguments

`J_target`	Numeric. Target Youden index value (must be in (0, 1)).
`mu2`	Numeric. Mean of the non-diseased population.
`sigma1`	Numeric. Base standard deviation of the diseased population.
`sigma2`	Numeric. Base standard deviation of the non-diseased population.
`p`	Numeric. Contamination probability (default: 0.1).
`tol`	Numeric. Root-finding tolerance (default: 1e-6).
`max_expand`	Integer. Maximum number of bracket-expansion iterations (default: 60).

Value

A numeric scalar, or `NA_real_` if the root cannot be found.

See Also

`find_mu1_from_J2`, `J_true_mixture`

Examples

```
find_mu1_from_J_mixture(J_target = 0.6, mu2 = 0, sigma1 = 1, sigma2 = 1, p = 0.1)
```

find_mu1_from_J2 *Find μ_1 from the Youden index under the normal model*

Description

Numerically solves for the mean of the diseased population μ_1 such that the theoretical Youden index equals `J2`, given the remaining parameters.

Usage

```
find_mu1_from_J2(J2, mu2, sigma2, sigma1, model)
```

Arguments

`J2`	Numeric. Target Youden index value.
`mu2`	Numeric. Mean of the non-diseased population.
`sigma2`	Numeric. Standard deviation of the non-diseased population.
`sigma1`	Numeric. Standard deviation of the diseased population.
`model`	Character. Currently only `"norm"` is supported.

Value

A numeric scalar, or `NA_real_` if the root cannot be found.

See Also

`J2.theoretical`, `find_mu1_from_J_mixture`

Examples

```
find_mu1_from_J2(J2 = 0.6, mu2 = 0, sigma2 = 1, sigma1 = 1, model = "norm")
```

generate_mixture_sample *Generate a sample from the contaminated normal mixture*

Description

Draws n observations from the mixture distribution used in the robustness study of Lai et al. (2012):

$$Y \sim (1 - B)\, N(\mu,\, \sigma_a^2) + B\, N(\mu,\, \sigma_b^2)$$

where $B \sim \text{Bernoulli}(p)$, $\sigma_a^2 = \sigma^2/1.1$ and $\sigma_b^2 = 2\sigma^2/1.1$.

Usage

```
generate_mixture_sample(n, mu, sigma, p = 0.1)
```

Arguments

n	Integer. Number of observations to generate.
mu	Numeric. Mean of the distribution.
sigma	Numeric. Base standard deviation (before scaling).
p	Numeric. Contamination probability (default: 0.1).

Value

A numeric vector of length n.

See Also

dmixnorm, pmixnorm

Examples

```
set.seed(1)
y <- generate_mixture_sample(n = 50, mu = 0, sigma = 1, p = 0.1)
summary(y)
```

---

generate_mixture_tables

Generate LaTeX tables for the mixture model simulation

Description

Produces two wide-format tables (coverage probability only, with σ_1^2 as column headers), one for the Youden index and one for the cut-point. These correspond to Tables 3 and 4 of Lai et al. (2012) for $p = 0.1$, and to the analogous tables for other values of p.

Usage

```
generate_mixture_tables(results_df, p, out_dir)
```

Arguments

results_df	Data frame as returned by run_parallel_grid with generator = "mixture".
p	Numeric. Contamination probability used in the simulation (included in captions and file names).
out_dir	Character. Directory where the .tex files are written.

Value

Invisibly NULL. Writes table_J_mixture_p=<p>.tex and table_c_mixture_p=<p>.tex to out_dir.

Examples

```
grid <- default_param_grid()[1:2, ]
results <- run_parallel_grid(grid, generator = "mixture",
                             n_mc = 10, K = 30, p = 0.1)
generate_mixture_tables(results, p = 0.1, out_dir = tempdir())
```

---

generate_normal_tables

Generate LaTeX tables for the normal model simulation

Description

Produces two long-format tables (coverage probability and average length, one for the Youden index and one for the cut-point), with σ_1^2 as the first grouping column. These correspond to Tables 1 and 2 of Lai et al. (2012).

Usage

```
generate_normal_tables(results_df, out_dir)
```

Arguments

results_df	Data frame as returned by run_parallel_grid with generator = "normal".
out_dir	Character. Directory where the .tex files are written.

Value

Invisibly NULL. Writes table_J_normal.tex and table_c_normal.tex to out_dir.

Examples

```
grid <- default_param_grid()[1:2, ]
results <- run_parallel_grid(grid, n_mc = 10, K = 30)
generate_normal_tables(results, out_dir = tempdir())
```

generate_param_grid *Build a custom parameter grid*

Description

Constructs a data frame of all combinations of the supplied parameter vectors and sample-size pairs, adding derived standard deviation columns.

Usage

```
generate_param_grid(var1, var2, mu2, J, n_pairs)
```

Arguments

var1	Numeric vector. Variances for the diseased population.
var2	Numeric vector. Variances for the non-diseased population.
mu2	Numeric vector. Means for the non-diseased population.
J	Numeric vector. Target Youden index values.
n_pairs	Integer matrix with two columns (n1, n2).

Value

A data frame with columns mu2, sigma1, sigma2, J, n1, n2, var1, var2.

See Also

default_param_grid

Examples

```
n_pairs <- matrix(c(10, 10, 20, 20), ncol = 2, byrow = TRUE)
generate_param_grid(var1 = c(1, 2), var2 = 1, mu2 = 0,
                    J = c(0.5, 0.7), n_pairs = n_pairs)
```

gpq_c *GPQ for the optimal cut-point*

Description

Computes the generalized pivotal quantity for the optimal cut-point (Equations 10-11 in Lai et al., 2012).

Usage

```
gpq_c(R_mu1, R_mu2, R_sigma1, R_sigma2, tol = 0.01)
```

Arguments

R_mu1	Numeric. GPQ realization for the mean of the diseased group.
R_mu2	Numeric. GPQ realization for the mean of the non-diseased group.
R_sigma1	Numeric. GPQ realization for the SD of the diseased group.
R_sigma2	Numeric. GPQ realization for the SD of the non-diseased group.
tol	Numeric. Tolerance for the equal-variance case (default: 1e-2).

Value

A numeric scalar.

Examples

```
gpq_c(R_mu1 = 2, R_mu2 = 0, R_sigma1 = 1, R_sigma2 = 1.2)
```

---

gpq_from_sample *Generate generalized pivotal quantities for one simulated sample*

Description

Implements the GPQ algorithm of Lai et al. (2012) for a single dataset drawn from two normal populations, producing Monte Carlo realizations of the GPQs for the Youden index and its optimal cut-point.

Usage

```
gpq_from_sample(y1, y2, K = 250, tol = 0.01)
```

Arguments

y1	Numeric vector. Observed sample from the diseased population.
y2	Numeric vector. Observed sample from the non-diseased population.
K	Integer. Number of GPQ iterations (default: 250).
tol	Numeric. Tolerance for the equal-variance case in gpq_c (default: 1e-2).

Value

A list with two numeric vectors of length K:

RJ GPQ realizations for the Youden index.

Rc GPQ realizations for the optimal cut-point.

References

Lai, C.-Y., Tian, L., & Schisterman, E. F. (2012). Exact confidence interval estimation for the Youden index and its corresponding optimal cut-point. *Computational Statistics & Data Analysis*, 56(5), 1103-1114.

Examples

```
set.seed(1)
y1 <- rnorm(30, mean = 2, sd = 1)
y2 <- rnorm(30, mean = 0, sd = 1)
gpq <- gpq_from_sample(y1, y2, K = 100)
quantile(gpq$RJ, probs = c(0.025, 0.975))
```

---

gpq_J *GPQ for the Youden index*

Description

Computes the generalized pivotal quantity for the Youden index (Equation 12 in Lai et al., 2012).

Usage

```
gpq_J(R_mu1, R_mu2, R_sigma1, R_sigma2, Rc)
```

Arguments

R_mu1	Numeric. GPQ realization for the mean of the diseased group.
R_mu2	Numeric. GPQ realization for the mean of the non-diseased group.
R_sigma1	Numeric. GPQ realization for the SD of the diseased group.
R_sigma2	Numeric. GPQ realization for the SD of the non-diseased group.
Rc	Numeric. GPQ realization for the optimal cut-point.

Value

A numeric scalar in $(-1, 1)$.

Examples

```
gpq_J(R_mu1 = 2, R_mu2 = 0, R_sigma1 = 1, R_sigma2 = 1.2, Rc = 1)
```

gpq_mu *GPQ for the mean*

Description

Computes the generalized pivotal quantity for the mean of one population (Equation 7 in Lai et al., 2012).

Usage

```
gpq_mu(ybar, s, n, t_value)
```

Arguments

ybar	Numeric. Observed sample mean.
s	Numeric. Observed sample standard deviation.
n	Integer. Sample size.
t_value	Numeric. Realization of a Student's t with n - 1 degrees of freedom.

Value

A numeric scalar.

Examples

```
gpq_mu(ybar = 5, s = 1.2, n = 30, t_value = 0.5)
```

gpq_sigma *GPQ for the standard deviation*

Description

Computes the generalized pivotal quantity for the standard deviation of one population (Equation 8 in Lai et al., 2012).

Usage

```
gpq_sigma(s2, v, n)
```

Arguments

s2	Numeric. Observed sample variance.
v	Numeric. Realization of a chi-squared with n - 1 degrees of freedom.
n	Integer. Sample size.

Value

A numeric scalar (standard deviation scale).

Examples

```
gpq_sigma(s2 = 1.5, v = 28.3, n = 30)
```

`J_true_mixture` *True Youden index and optimal cut-point under the mixture model*

Description

Numerically maximises the Youden index over all possible cut-points for two contaminated normal mixture distributions.

Usage

```
J_true_mixture(mu1, mu2, sigma1, sigma2, p = 0.1)
```

Arguments

`mu1`	Numeric. Mean of the diseased population.
`mu2`	Numeric. Mean of the non-diseased population.
`sigma1`	Numeric. Base standard deviation of the diseased population.
`sigma2`	Numeric. Base standard deviation of the non-diseased population.
`p`	Numeric. Contamination probability (default: 0.1).

Value

A list with two elements:

J The maximum Youden index.

c The optimal cut-point that achieves it.

See Also

`find_mu1_from_J_mixture`

Examples

```
J_true_mixture(mu1 = 1.68, mu2 = 0, sigma1 = 1, sigma2 = 1, p = 0.1)
```

J2.theoretical *Theoretical Youden index under the normal model*

Description

Computes the true Youden index for two normal populations given their means and standard deviations.

Usage

```
J2.theoretical(parameters, model)
```

Arguments

parameters	Numeric vector or matrix with four columns in the order $(\mu_2, \mu_1, \sigma_2, \sigma_1)$. If a vector is supplied it is coerced to a one-row matrix.
model	Character. Currently only "norm" is supported.

Value

A numeric vector of Youden index values, one per row of parameters.

See Also

find_mu1_from_J2

Examples

```
# (mu2, mu1, sigma2, sigma1)
J2.theoretical(c(0, 1.68, 1, 1), model = "norm")
```

mix_sd *Standard deviations of the two mixture components*

Description

Returns the standard deviations of the non-contaminated and contaminated components of the mixture as defined in Lai et al. (2012).

Usage

```
mix_sd(sigma)
```

Arguments

sigma	Numeric. Base standard deviation.

Value

A named numeric vector with elements `sd_a` ($\sigma/\sqrt{1.1}$) and `sd_b` ($\sigma\sqrt{2/1.1}$).

Examples

```
mix_sd(sigma = 1)
```

`pmixnorm` *CDF of the contaminated normal mixture*

Description

CDF of the contaminated normal mixture

Usage

```
pmixnorm(x, mu, sigma, p = 0.1)
```

Arguments

`x`	Numeric vector. Points at which to evaluate the CDF.
`mu`	Numeric. Mean of the distribution.
`sigma`	Numeric. Base standard deviation.
`p`	Numeric. Contamination probability (default: 0.1).

Value

A numeric vector of cumulative probabilities.

See Also

`dmixnorm`, `generate_mixture_sample`

Examples

```
pmixnorm(x = 0, mu = 0, sigma = 1, p = 0.1)
```

run_one_row *Run the simulation for a single row of the parameter grid*

Description

Convenience wrapper around run_simulation that accepts a single-row data frame (as returned by subsetting the output of default_param_grid) and returns a one-row summary data frame.

Usage

```
run_one_row(
  row,
  generator = c("normal", "mixture"),
  n_mc = 200,
  K = 250,
  p = 0.1
)
```

Arguments

row	A one-row data frame with columns mu2, sigma1, sigma2, J, n1, n2, var1, var2.
generator	Character. "normal" or "mixture".
n_mc	Integer. Number of Monte Carlo replications (default: 200).
K	Integer. Number of GPQ iterations per replication (default: 250).
p	Numeric. Contamination probability. Ignored when generator = "normal" (default: 0.1).

Value

A one-row data frame with columns mu2, var1, var2, J, n1, n2, coverage_J, length_J, coverage_c, length_c, generator, p.

See Also

run_simulation, run_parallel_grid

Examples

```
row <- default_param_grid()[1, ]
set.seed(1)
run_one_row(row, n_mc = 10, K = 30)
```

run_parallel_grid *Run the simulation in parallel, detecting the OS automatically*

Description

Uses `mclapply` on Unix/macOS and `doParallel+foreach` on Windows.

Usage

```
run_parallel_grid(
  df_params,
  generator = c("normal", "mixture"),
  n_mc = 200,
  K = 250,
  p = 0.1,
  n_cores = getOption("mc.cores", 2L)
)
```

Arguments

`df_params`	Data frame of parameter combinations (from `default_param_grid` or `generate_param_grid`).
`generator`	Character. `"normal"` or `"mixture"`.
`n_mc`	Integer. Number of Monte Carlo replications.
`K`	Integer. Number of GPQ iterations per replication.
`p`	Numeric. Mixture proportion. Ignored when `generator = "normal"`; passed through to `run_one_row` but has no effect on the normal simulation.
`n_cores`	Integer. Number of parallel workers to use. Defaults to `getOption("mc.cores", 2L)`, capped at the number of cores actually detected; pass a higher value explicitly to use more (CRAN policy caps the *default* number of cores a package may use at 2, but the caller may always opt into more).

Value

A data frame with one row per parameter combination.

Examples

```
grid <- default_param_grid()[1:2, ]
run_parallel_grid(grid, n_mc = 10, K = 30)
```

`run_simulation` *Run the Monte Carlo simulation for a single parameter scenario*

Description

Repeatedly draws paired samples under the normal or contaminated-mixture model, computes GPQ-based confidence intervals for the Youden index and its optimal cut-point via `gpq_from_sample`, and summarises empirical coverage and mean interval length over `n_mc` replications.

Usage

```
run_simulation(
  mu2,
  sigma1,
  sigma2,
  J,
  n1,
  n2,
  n_mc = 200,
  K = 250,
  alpha = 0.05,
  generator = c("normal", "mixture"),
  p = 0.1
)
```

Arguments

`mu2`	Numeric. Mean of the non-diseased population.
`sigma1`	Numeric. Standard deviation of the diseased population.
`sigma2`	Numeric. Standard deviation of the non-diseased population.
`J`	Numeric. Target (nominal) Youden index.
`n1`	Integer. Sample size for the diseased population.
`n2`	Integer. Sample size for the non-diseased population.
`n_mc`	Integer. Number of Monte Carlo replications (default: 200).
`K`	Integer. Number of GPQ iterations per replication, passed to `gpq_from_sample` (default: 250).
`alpha`	Numeric. Significance level for the confidence intervals (default: 0.05, giving 95% intervals).
`generator`	Character. `"normal"` or `"mixture"`.
`p`	Numeric. Contamination probability, used only when `generator = "mixture"` (default: 0.1).

Value

A list with elements `params` (the scenario's parameters, including the derived `mu1`), `J` and `c`, each a list with `coverage` and `mean_length`.

See Also

`run_one_row`, `run_parallel_grid`

Examples

```
set.seed(1)
run_simulation(mu2 = 0, sigma1 = 1, sigma2 = 1, J = 0.6,
                n1 = 20, n2 = 20, n_mc = 20, K = 50)
```

Index

calculate_mu1_for_dataframe, 2

default_param_grid, 3, *9*, *16*
dmixnorm, 3, *7*, *15*

eq.J2, 4

find_mu1_from_J2, *2*, *4*, *5*, 6, *14*
find_mu1_from_J_mixture, 5, *6*, *13*

generate_mixture_sample, *4*, 6, *15*
generate_mixture_tables, 7
generate_normal_tables, 8
generate_param_grid, *3*, 9
gpq_c, 9, *10*
gpq_from_sample, 10, *18*
gpq_J, 11
gpq_mu, 12
gpq_sigma, 12

J2.theoretical, *6*, 14
J_true_mixture, *5*, 13

mix_sd, 14

pmixnorm, *4*, *7*, 15

run_one_row, 16, *19*
run_parallel_grid, *3*, *16*, 17, *19*
run_simulation, *16*, 18