Package 'ppRep'

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Title Analysis of Replication Studies using Power Priors

Description Provides functionality for Bayesian analysis of replication studies using power prior approaches (Pawel et al., 2023) <doi:10.1007/s11749-023-00888-5>.

License GPL-3

Encoding UTF-8

Imports hypergeo

Suggests roxygen2, tinytest, cubature

NeedsCompilation no

RoxygenNote 7.2.3

URL https://github.com/SamCH93/ppRep

BugReports https://github.com/SamCH93/ppRep/issues

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R topics documented:

bfPPalpha *Bayes factor for testing power parameter*

Description

This function computes the Bayes factor contrasting $H_1\colon \alpha = 1$ to $H_0\colon \alpha < 1$ for the replication data assuming a normal likelihood. The power parameter α indicates how much the normal likelihood of the original data is raised to and then incorporated in the prior for the effect size θ (e.g., for $\alpha = 0$ the original data are completely discounted). Under H_0, the power parameter can either be fixed to 0, or it can have a beta distribution $\alpha|H_0 \sim \text{Beta}(1, \texttt{y})$. For the fixed power parameter case, the specification of an unit-information prior $\theta \sim \text{N}(0, \texttt{uv})$ for the effect size θ is required as the prior is otherwise not proper.

Usage

```
bfPPalpha(tr, sr, to, so, y = 2, uv = NA, ...)
```

Arguments

tr	Effect estimate of the replication study.
sr	Standard error of the replication effect estimate.
to	Effect estimate of the original study.
so	Standard error of the replication effect estimate.
y	Number of failures parameter for beta prior of power parameter under H_0. Has to be larger than 1 so that density is monotonically decreasing. Defaults to 2 (a linearly decreasing prior with zero density at 1). Is only taken into account when uv = NA.
uv	Variance of the unit-information prior for the effect size that is used for testing the simple hypothesis $H_0\colon \alpha = 0$. Defaults to NA.
...	Additional arguments passed to stats::integrate.

Value

Bayes factor (BF > 1 indicates evidence for H_0, whereas BF < 1 indicates evidence for H_1)

Author(s)

Samuel Pawel

See Also

bfPPtheta

Examples

```
## use unit variance of 2
bfPPalpha(tr = 0.09,  sr = 0.0518, to = 0.205, so = 0.0506, uv = 2)

## use beta prior alpha|H1 ~ Be(1, y = 2)
bfPPalpha(tr = 0.09,  sr = 0.0518, to = 0.205, so = 0.0506, y = 2)
```

`bfPPtheta` *Bayes factor for testing effect size*

Description

This function computes the Bayes factor contrasting $H_0 \colon \theta = 0$ to $H_1 \colon \theta \sim f(\theta|\mathtt{to}, \mathtt{so}, \alpha)$ for the replication data assuming a normal likelihood. The prior of the effect size θ under H_1 is the posterior of the effect size obtained from combining a normal likelihood of the original data raised to the power of α with a flat initial prior with a. Under H_1, the power parameter can either be fixed to some value between 0 and 1, or it can have a beta distribution $\alpha|H_1 \sim \text{Beta}(\mathtt{x}, \mathtt{y})$.

Usage

```
bfPPtheta(tr, sr, to, so, x = 1, y = 1, alpha = NA, ...)
```

Arguments

`tr`	Effect estimate of the replication study.
`sr`	Standard error of the replication effect estimate.
`to`	Effect estimate of the original study.
`so`	Standard error of the replication effect estimate.
`x`	Number of successes parameter for beta prior of power parameter under H_1. Defaults to `1`. Is only taken into account when `alpha = NA`.
`y`	Number of failures parameter for beta prior of power parameter under H_1. Defaults to `1`. Is only taken into account when `alpha = NA`.
`alpha`	Power parameter under H_1. Can be set to a number between 0 and 1. Defaults to `NA`.
`...`	Additional arguments passed to `stats::integrate`.

Value

Bayes factor (BF > 1 indicates evidence for H_0, whereas BF < 1 indicates evidence for H_1)

Author(s)

Samuel Pawel

See Also

bfPPalpha

Examples

```
## uniform prior on power parameter
bfPPtheta(tr = 0.09,  sr = 0.0518, to = 0.205, so = 0.0506)

## power parameter fixed to alpha = 1
bfPPtheta(tr = 0.090, sr = 0.0518, to = 0.205, so = 0.0506, alpha = 1)
```

---

margLik *Marginal likelihood of replication effect estimate*

Description

This function computes the marginal likelihood of the replication effect estimate `tr` under the power prior model

$$f(\texttt{tr}|\texttt{to}, \texttt{so}, \texttt{sr}, \texttt{x}, \texttt{y}) = \int_0^1 \int_{-\infty}^{\infty} \mathrm{N}(\texttt{tr}; \theta, \texttt{sr}^2) \times \mathrm{N}(\theta; \mu, \phi) \times \mathrm{Beta}(\alpha; \texttt{x}, \texttt{y}) \, \mathrm{d}\theta \, \mathrm{d}\alpha$$

with $\phi = 1/(1/\texttt{v} + \alpha/\texttt{so}^2)$ and $\mu = \phi\{(\alpha \times \texttt{to})/\texttt{so}^2 + \texttt{m}/\texttt{v}\}$ using numerical integration.

Usage

```
margLik(tr, to, sr, so, x = 1, y = 1, m = 0, v = Inf, ...)
```

Arguments

`tr`	Effect estimate of the replication study.
`to`	Effect estimate of the original study.
`sr`	Standard error of the replication effect estimate.
`so`	Standard error of the replication effect estimate.
`x`	Number of successes parameter of beta prior for α. Defaults to `1`.
`y`	Number of failures parameter of beta prior for α. Defaults to `1`.
`m`	Mean parameter of initial normal prior for θ. Defaults to `0`.
`v`	Variance parameter of initial normal prior for θ. Defaults to `Inf` (uniform prior).
`...`	Additional arguments passed to `stats::integrate`.

Value

Marginal likelihood

Author(s)

Samuel Pawel

plotPP *Plot joint and marginal posterior distributions*

Description

This convenience function computes and, if desired, visualizes the joint posterior density of effect size θ and power parameter α, as well as the marginal posterior densities of effect size θ and power parameter α individually. See the functions postPP, postPPalpha, and postPPtheta for more details on their computation.

Usage

```
plotPP(
  tr,
  sr,
  to,
  so,
  x = 1,
  y = 1,
  m = 0,
  v = Inf,
  thetaRange = c(tr - 3 * sr, tr + 3 * sr),
  alphaRange = c(0, 1),
  nGrid = 100,
  plot = TRUE,
  CI = FALSE,
  ...
)
```

Arguments

tr	Effect estimate of the replication study.
sr	Standard error of the replication effect estimate.
to	Effect estimate of the original study.
so	Standard error of the replication effect estimate.
x	Number of successes parameter of beta prior for α. Defaults to 1.
y	Number of failures parameter of beta prior for α. Defaults to 1.
m	Mean parameter of initial normal prior for θ. Defaults to 0.
v	Variance parameter of initial normal prior for θ. Defaults to Inf (uniform prior).
thetaRange	Range of effect sizes. Defaults to three standard errors around the replication effect estimate.
alphaRange	Range of power parameters. Defaults to the range between zero and one.
nGrid	Number of grid points. Defaults to 100.

plot	Logical indicating whether data should be plotted. If FALSE only the data used for plotting are returned.
CI	Logical indicating whether 95% highest posterior credible intervals should be plotted. Defaults to FALSE.
...	Additional arguments passed to stats::integrate for computation of posterior densities and highest posterior density credible intervals.

Value

Plots joint and marginal posterior densities, invisibly returns a list with the data for the plots.

Author(s)

Samuel Pawel

See Also

postPP, postPPalpha, postPPtheta

Examples

```
plotPP(tr = 0.2, sr = 0.05, to = 0.15, so = 0.05)
```

---

postPP *Posterior density of effect size and power parameter*

Description

This function computes the posterior density of effect size θ and power parameter α assuming a normal likelihood for original and replication effect estimate. A power prior for θ is constructed by updating an initial normal prior $\theta \sim \mathrm{N}(\mathsf{m}, \mathsf{v})$ with the likelihood of the original data raised to the power of α. A marginal beta prior $\alpha \sim \mathrm{Beta}(\mathsf{x}, \mathsf{y})$ is assumed.

Usage

```
postPP(theta, alpha, tr, sr, to, so, x = 1, y = 1, m = 0, v = Inf, ...)
```

Arguments

theta	Effect size. Has to be of length one or the same length as alpha.
alpha	Power parameter. Has to be of length one or the same length as theta.
tr	Effect estimate of the replication study.
sr	Standard error of the replication effect estimate.
to	Effect estimate of the original study.
so	Standard error of the replication effect estimate.
x	Number of successes parameter of beta prior for α. Defaults to 1.

y	Number of failures parameter of beta prior for α. Defaults to 1.
m	Mean parameter of initial normal prior for θ. Defaults to 0.
v	Variance parameter of initial normal prior for θ. Defaults to Inf (uniform prior).
...	Additional arguments passed to stats::integrate.

Value

Posterior density

Author(s)

Samuel Pawel

See Also

postPPalpha, postPPtheta, plotPP

Examples

```
alpha <- seq(0, 1, length.out = 200)
theta <- seq(0, 0.3, length.out = 200)
parGrid <- expand.grid(alpha = alpha, theta = theta)
postdens <- postPP(theta = parGrid$theta, alpha = parGrid$alpha, tr = 0.1,
                   sr = 0.05, to = 0.2, so = 0.05)
postdensMat <- matrix(data = postdens, ncol = 200, byrow = TRUE)
filled.contour(x = theta, y = alpha, z = postdensMat,
               xlab = bquote("Effect size" ~ theta),
               ylab = bquote("Power parameter" ~ alpha), nlevels = 15,
               color.palette = function(n) hcl.colors(n = n, palette = "viridis"))
```

---

postPPalpha *Marginal posterior distribution of power parameter*

Description

These functions compute the marginal posterior of the power parameter α. A power prior for θ is constructed by updating an initial normal prior $\theta \sim \mathrm{N}(\mathtt{m}, \mathtt{v})$ with the likelihood of the original data raised to the power of α. A marginal beta prior $\alpha \sim \mathrm{Beta}(\mathtt{x}, \mathtt{y})$ is assumed.

Usage

```
postPPalpha(alpha, tr, sr, to, so, x = 1, y = 1, m = 0, v = Inf, ...)

postPPalphaHPD(level = 0.95, tr, sr, to, so, x = 1, y = 1, m = 0, v = Inf, ...)
```

Arguments

alpha	Power parameter. Can be a vector.
tr	Effect estimate of the replication study.
sr	Standard error of the replication effect estimate.
to	Effect estimate of the original study.
so	Standard error of the replication effect estimate.
x	Number of successes parameter of beta prior α. Defaults to 1.
y	Number of failures parameter of beta prior α. Defaults to 1.
m	Mean parameter of initial normal prior for θ. Defaults to 0.
v	Variance parameter of initial normal prior for θ. Defaults to Inf (uniform prior).
...	Additional arguments passed to stats::integrate.
level	Credibility level of the highest posterior density interval. Defaults to 0.95.

Value

postPPalpha returns the marginal posterior density of the power parameter.

postPPalphaHPD returns the highest marginal posterior density interval of the power parameter.

Author(s)

Samuel Pawel

See Also

postPP, postPPtheta, plotPP

Examples

```
alpha <- seq(0, 1, 0.001)
margpostdens <- postPPalpha(alpha = alpha, tr = 0.1, to = 0.2, sr = 0.05, so = 0.05)
plot(alpha, margpostdens, type = "l", xlab = bquote("Power parameter" ~ alpha),
     ylab = "Marginal posterior density", las = 1)
```

---

postPPtheta *Marginal posterior distribution of effect size*

Description

These functions compute the marginal posterior of the effect size θ. A power prior for θ is constructed by updating an initial normal prior $\theta \sim \mathrm{N}(\mathsf{m}, \mathsf{v})$ with likelihood of the original data raised to the power of α. The power parameter α can either be fixed to some value between 0 and 1 or it can have a beta prior distribution $\alpha \sim \mathrm{Beta}(\mathsf{x}, \mathsf{y})$.

Usage

```
postPPtheta(
  theta,
  tr,
  sr,
  to,
  so,
  x = 1,
  y = 1,
  alpha = NA,
  m = 0,
  v = Inf,
  hypergeo = FALSE,
  ...
)

postPPthetaHPD(
  level,
  tr,
  sr,
  to,
  so,
  x = 1,
  y = 1,
  alpha = NA,
  m = 0,
  v = Inf,
  thetaRange = tr + c(-1, 1) * stats::qnorm(p = (1 + level)/2) * sr * 3,
  quantileRange = c((1 - level) * 0.2, (1 - level) * 0.8),
  ...
)
```

Arguments

theta	Effect size. Can be a vector.
tr	Effect estimate of the replication study.
sr	Standard error of the replication effect estimate.
to	Effect estimate of the original study.
so	Standard error of the replication effect estimate.
x	Number of successes parameter for beta prior of power parameter α. Defaults to 1. Is only taken into account when alpha = NA.
y	Number of failures parameter for beta prior of power parameter α. Defaults to 1. Is only taken into account when alpha = NA.
alpha	Power parameter. Can be set to a number between 0 and 1. Defaults to NA (a beta prior on the power parameter).
m	Mean parameter of initial normal prior for θ. Defaults to 0.

v	Variance parameter of initial normal prior for θ. Defaults to `Inf` (uniform prior).
hypergeo	Logical indicating whether for uniform priors, the marginal posterior should be computed with the hypergeometric function. Defaults to `FALSE` (using numerical integration instead).
...	Additional arguments passed to `stats::integrate` or `hypergeo::genhypergeo` (depending on the `hypergeo` argument).
level	Credibility level of the highest posterior density interval. Defaults to `0.95`.
thetaRange	The numerical search range for the effect size. Defaults to the `level*100`% confidence inteval range inflated by a factor of three. We recommend changing this argument only if there are numerical problems in calculating the HPD interval.
quantileRange	The numerical search range for the lower posterior quantile of the HPD interval. Defaults to the range between `(1 -level)*0.2` and `(1 - level)*0.8`. We recommend changing this argument only if there are numerical problems in calculating the HPD interval.

Value

`postPPtheta` returns the marginal posterior density of the effect size.

`postPPthetaHPD` returns the highest marginal posterior density interval of the effect size (this may take a while).

Author(s)

Samuel Pawel

See Also

`postPP`, `postPPalpha`, `plotPP`

Examples

```
theta <- seq(0, 0.6, 0.001)
margpostdens <- postPPtheta(theta = theta, tr = 0.1, to = 0.2, sr = 0.05, so = 0.05)
plot(theta, margpostdens, type = "l", xlab = bquote("Effect size" ~ theta),
     ylab = "Marginal posterior density", las = 1)
```

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