Package 'fbst'

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Type Package

Title The Full Bayesian Evidence Test, Full Bayesian Significance Test and the e-Value

Version 1.5

Date 2021-04-12

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Description Provides access to a range of functions for computing and visualizing the Full Bayesian Significance Test (FBST) and the e-value for testing a sharp hypothesis against its alternative, and the Full Bayesian Evidence Test (FBET) and the (generalized) Bayesian evidence value for testing a composite (or interval) hypothesis against its alternative. The methods are widely applicable as long as a posterior MCMC sample is available. For details on the computation and theory of the FBST see <arXiv:2005.13181>.

Imports bayestestR, methods

Suggests BayesFactor, knitr, rmarkdown

License GPL-3

VignetteBuilder knitr

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`fbst-package` *The Full Bayesian Evidence Test, Full Bayesian Significance Test and the e-Value*

Description

Provides access to a range of functions for computing and visualizing the Full Bayesian Significance Test (FBST) and the e-value for testing a sharp hypothesis against its alternative, and the Full Bayesian Evidence Test (FBET) and the (generalized) Bayesian evidence value for testing a composite (or interval) hypothesis against its alternative. The methods are widely applicable as long as a posterior MCMC sample is available. For details on the computation and theory of the FBST see <arXiv:2005.13181>.

Details

Package for conducting the Full Bayesian Evidence Test (FBET) and the Full Bayesian Significance Test (FBST). The FBST is a Bayesian hypothesis test for testing a sharp hypothesis against its alternative by calculating the e-value, the Bayesian evidence against the null hypothesis. The FBET is a generalization of the underlying Pereira-Stern theory of the FBST and allows for testing interval hypotheses. It provides the Bayesian evidence value, or generalized e-value, which includes the e-value of the FBST as a special case. The Bayesian evidence value is based on the relative surprise function to a reference function. In the FBST, the tangential set corresponding to a sharp null hypothesis serves for quantifying the Bayesian evidence. In the FBET, the Bayesian evidence interval serves for quantifying the Bayesian evidence, which has a strong analogy to the Bayes factor. Next to the core functions, helper functions and visualizations of the results of a FBST and FBET are provided in the package.

Package:	fbst
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Title:	The Full Bayesian Evidence Test, Full Bayesian Significance Test and the e-Value
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Suggests:	BayesFactor, knitr, rmarkdown
License:	GPL-3

VignetteBuilder: knitr

Index of help topics:

Author(s)

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References

For a details, see: https://arxiv.org/abs/2001.10577 and https://arxiv.org/pdf/2001.10577.pdf.

`access-method` *Returns an object from an object of class* `fbst`.

Description

Returns an object from an object of class `fbst`

Details

-

Value

-

Author(s)

Riko Kelter

References

For a details, see: https://arxiv.org/abs/2001.10577 and https://arxiv.org/pdf/2001.10577.pdf.

Examples

```
set.seed(57)
grp1=rnorm(50,0,1.5)
grp2=rnorm(50,0.8,3.2)

p = as.vector(BayesFactor::ttestBF(x=grp1,y=grp2,
  posterior = TRUE, iterations = 3000,
  rscale = "medium")[,4])

# flat reference function
res = fbst(posteriorDensityDraws = p, nullHypothesisValue = 0,
dimensionTheta = 3, dimensionNullset = 2)

# Return the e-value from an fbst object
res$eValue
```

---

access_fbet-method *Returns an object from an object of class* fbet.

Description

Returns an object from an object of class fbet

Details

-

Value

-

Author(s)

Riko Kelter

References

For a details, see: https://arxiv.org/abs/2001.10577 and https://arxiv.org/pdf/2001.10577.pdf.

Examples

```
set.seed(57)
grp1=rnorm(50,0,1.5)
grp2=rnorm(50,0.8,3.2)

p = as.vector(BayesFactor::ttestBF(x=grp1,y=grp2,
  posterior = TRUE, iterations = 3000,
  rscale = "medium")[,4])

# flat reference function
res = fbet(p, interval = c(-0.1,0.1), nu=1, FUN=NULL, par=NULL)

# Return the Bayesian evidence value for the interval null hypothesis
res$eValueH0
```

---

fbet *fbet*

Description

The function computes the Full Bayesian Evidence Test (FBST) and the Bayesian evidence value (the generalized e-value which obtains the e-value of the FBST as a special case), which is the Bayesian evidence against an interval null hypothesis. The function assumes posterior MCMC draws and constructs a posterior density based on a kernel density estimator subsequently. The Bayesian evidence interval is computed using a linear search based on the evidence-threshold and the calculation of the Bayesian evidence value is performed using numerical integration.

Usage

```
fbet(posteriorDensityDraws, interval, nu=1, FUN=NULL, par=NULL)
```

Arguments

posteriorDensityDraws	Vector of MCMC posterior parameter draws
interval	Vector of two numerical values containing the boundaries of the interval null hypothesis to be tested
nu	Numerical value which provides the evidence-threshold based on which the Bayesian evidence interval is calculated
FUN	Reference function
par	Additional parameters of the reference function

Details

If no reference function is specified, a flat reference function $r(\theta) = 1$ is used as default reference function.

Value

Returns an object of class fbet.

Author(s)

Riko Kelter

References

For a details, see: https://arxiv.org/abs/2001.10577.

Examples

```
set.seed(57)
grp1=rnorm(50,0,1.5)
grp2=rnorm(50,0.3,3.2)

p = as.vector(BayesFactor::ttestBF(x=grp1,y=grp2,
  posterior = TRUE, iterations = 3000,
  rscale = "medium")[,4])

# flat reference function, nu = 0
res = fbet(p, interval = c(-0.1,0.1), nu=0, FUN=NULL, par=NULL)
summary(res)
plot(res)

# flat reference function, nu = 1
res = fbet(p, interval = c(-0.1,0.1), nu=1, FUN=NULL, par=NULL)
summary(res)
plot(res)

# medium Cauchy C(0,1) reference function, nu = 1
res_med = fbet(p = p, interval = c(-0.1,0.1), nu = 1,
FUN = dcauchy, par = list(location = 0, scale=sqrt(2)))
summary(res_med)
plot(res_med)
```

---

fbet-class *Class* "fbet-class"

Description

Class for modelling the results of a Full Bayesian Evidence Test

Objects from the Class

Store the results of a FBET

Slots

`data`: Object of class `"list"` holding the results of the Full Bayesian Evidence Test. `posteriorDensityDraws` holds the posterior MCMC parameter draws, `posteriorDensityDrawsSorted` stores the sorted posterior MCMC parameter draws, `postDensValues` stores the posterior density values, `indices` stores the indices for deciding which values pass the evidence-threshold ν, `interval` stores the boundaries of the interval null hypothesis, `referenceFunction` stores the name of the reference function used, `nu` specifies the evidence-threshold used for computation of the Bayesian evidence interval, `evidenceInterval` holds the endpoints of the resulting Bayesian evidence interval, `eValueH0` holds the Bayesian evidence value in favour of the interval null hypothesis, `eValueH1` holds the Bayesian evidence value in favour of the alternative hypothesis (or equivalently, against the interval null hypothesis)

`fbst` *fbst*

Description

The function computes the Full Bayesian Significance Test (FBST) and the e-value, which is the Bayesian evidence against a sharp null hypothesis. The function assumes posterior MCMC draws and constructs a posterior density based on a kernel density estimator subsequently.

Usage

```
fbst(posteriorDensityDraws, nullHypothesisValue, FUN, par,
dimensionTheta, dimensionNullset)
```

Arguments

`posteriorDensityDraws`	Vector of MCMC posterior parameter draws
`nullHypothesisValue`	Parameter value belonging to the sharp null hypothesis
`FUN`	Reference function
`par`	Additional parameters of the reference function
`dimensionTheta`	Dimension of the parameter space
`dimensionNullset`	Dimension of the null set corresponding to the null hypothesis

Details

If no reference function is specified, a flat reference function $r(\theta) = 1$ is used as default reference function.

Value

Returns an object of class fbst.

Author(s)

Riko Kelter

References

For a details, see: https://arxiv.org/abs/2001.10577.

Examples

```
set.seed(57)
grp1=rnorm(50,0,1.5)
grp2=rnorm(50,0.8,3.2)

p = as.vector(BayesFactor::ttestBF(x=grp1,y=grp2,
  posterior = TRUE, iterations = 3000,
  rscale = "medium")[,4])

# flat reference function
res = fbst(posteriorDensityDraws = p, nullHypothesisValue = 0,
dimensionTheta = 2, dimensionNullset = 1)
summary(res)
plot(res)

# medium Cauchy C(0,1) reference function
res_med = fbst(posteriorDensityDraws = p, nullHypothesisValue = 0, dimensionTheta = 2,
dimensionNullset = 1, FUN = dcauchy, par = list(location = 0, scale = sqrt(2)/2))
summary(res_med)
plot(res_med)
```

---

fbst-class *Class* "fbst-class"

Description

Class for modelling the results of a Full Bayesian Significance Test

Objects from the Class

Store the results of a FBST

Slots

`data`: Object of class `"list"` holding the results of the Full Bayesian Significance Test. `posteriorDensityDraws` holds the posterior MCMC parameter draws, `postEffSizeSorted` stores the sorted posterior MCMC parameter draws, `densZero` stores the surprise function value at the sharp null hypothesis parameter value, `postDensValues` stores the posterior density values, `indices` stores the indices for deciding which values are located inside the tangential set, `nullHypothesisValue` stores the sharp null hypothesis parameter value, `referenceFunction` holds the name of the reference function used, `dimensionTheta` holds the dimension of the parameter space,

dimensionNullset holds the dimension of the null set corresponding to the null hypothesis, eValue holds the Bayesian evidence against the sharp null hypothesis, the e-value, pValue holds the p-value associated with the Bayesian e-value in favour of the sharp null hypothesis, sev_H_0 holds the standardized e-value as a replacement of the frequentist p-value.

---

names.fbet *names.fbet*

Description

Plots the names of the objects stored in the data object of a Full Bayesian Evidence Test.

Usage

```
## S3 method for class 'fbet'
names(x)
```

Arguments

x	An Object of class "fbet".

Details

Plots the names of the objects stored in the data object of a Full Bayesian Evidence Test.

Value

Returns a list of names.

Author(s)

Riko Kelter

References

For a details, see: https://arxiv.org/abs/2001.10577 and https://arxiv.org/pdf/2001.10577.pdf.

Examples

```
set.seed(57)
grp1=rnorm(50,0,1.5)
grp2=rnorm(50,0.8,3.2)

p = as.vector(BayesFactor::ttestBF(x=grp1,y=grp2,
  posterior = TRUE, iterations = 3000,
  rscale = "medium")[,4])

# flat reference function
res = fbet(p, interval = c(-0.1,0.1), nu=1, FUN=NULL, par=NULL)
names(res)
```

names.fbst *names.fbst*

Description

Plots the names of the objects stored in the data object of a Full Bayesian Significance Test.

Usage

```
## S3 method for class 'fbst'
names(x)
```

Arguments

x	An Object of class "fbst".

Details

Plots the names of the objects stored in the data object of a Full Bayesian Significance Test.

Value

Returns a list of names.

Author(s)

Riko Kelter

References

For a details, see: https://arxiv.org/abs/2001.10577 and https://arxiv.org/pdf/2001.10577.pdf.

Examples

```
set.seed(57)
grp1=rnorm(50,0,1.5)
grp2=rnorm(50,0.8,3.2)

p = as.vector(BayesFactor::ttestBF(x=grp1,y=grp2,
  posterior = TRUE, iterations = 3000,
  rscale = "medium")[,4])

# flat reference function
res = fbst(posteriorDensityDraws = p, nullHypothesisValue = 0,
dimensionTheta = 2, dimensionNullset = 1)
names(res)
```

plot.fbet *plot.fbet*

Description

Plots the results of a Full Bayesian Evidence Test.

Usage

```
## S3 method for class 'fbet'
plot(x, ..., leftBoundary = -100, rightBoundary = 100)
```

Arguments

x	An Object of class "fbet".
...	Additional parameters, see "plot(x,...)".
leftBoundary	x-coordinate for the left boundary to which is used for visualising the results. Defaults to -100.
rightBoundary	x-coordinate for the right boundary to which is used for visualising the results. Defaults to 100.

Details

Plots the resulting surprise function, the interval null hypothesis (dotted blue lines), the resulting Bayesian evidence interval (solid blue lines), the evidence-threshold ν (dotted black line) and the resulting Bayesian evidence values. The Bayesian evidence value in favour of the interval null hypothesis is visualized as the blue area, and the Bayesian evidence value in favour of the alternative hypothesis is visualized as the red area.

Value

Returns a plot.

Author(s)

Riko Kelter

References

For a details, see: https://arxiv.org/abs/2001.10577 and https://arxiv.org/pdf/2001.10577.pdf.

Examples

```
set.seed(57)
grp1=rnorm(50,0,1.5)
grp2=rnorm(50,0.3,3.2)

p = as.vector(BayesFactor::ttestBF(x=grp1,y=grp2,
  posterior = TRUE, iterations = 3000,
  rscale = "medium")[,4])

# flat reference function
res = fbet(p, interval = c(-0.1,0.1), nu=1, FUN=NULL, par=NULL)
summary(res)
plot(res)
```

`plot.fbst` *plot.fbst*

Description

Plots the results of a Full Bayesian Significance Test.

Usage

```
## S3 method for class 'fbst'
plot(x, ..., leftBoundary = -100, rightBoundary = 100)
```

Arguments

`x`	An Object of class `"fbst"`.
`...`	Additional parameters, see `"plot(x,...)"`.
`leftBoundary`	x-coordinate for the left boundary to which is used for visualising the evidence in support of the null hypothesis. Defaults to -100.
`rightBoundary`	x-coordinate for the right boundary to which is used for visualising the evidence in support of the null hypothesis. Defaults to 100.

Details

Plots the surprise function, the supremum of the surprise function restricted to the null set (blue point) and visualises the Bayesian e-value against the sharp null hypothesis as the blue shaded area under the surprise function. The Bayesian e-value in favour of the sharp null hypothesis is visualised as the red shaded area under the surprise function.

Value

Returns a plot.

Author(s)

Riko Kelter

References

For a details, see: https://arxiv.org/abs/2001.10577 and https://arxiv.org/pdf/2001.10577.pdf.

Examples

```
set.seed(57)
grp1=rnorm(50,0,1.5)
grp2=rnorm(50,0.8,3.2)

p = as.vector(BayesFactor::ttestBF(x=grp1,y=grp2,
  posterior = TRUE, iterations = 3000,
  rscale = "medium")[,4])

# flat reference function
res = fbst(posteriorDensityDraws = p, nullHypothesisValue = 0,
dimensionTheta = 2, dimensionNullset = 1)
plot(res)
```

---

show.fbet *show.fbet*

Description

Prints the main results of a Full Bayesian Evidence Test to the console.

Usage

```
## S3 method for class 'fbet'
show(object)
```

Arguments

object	An Object of class "fbet".

Details

Shows the main results of a Full Bayesian Evidence Test stored in an object of class fbet.

Value

Prints the results onto the console.

Author(s)

Riko Kelter

References

For a details, see: https://arxiv.org/abs/2001.10577 and https://arxiv.org/pdf/2001.10577.pdf.

Examples

```
set.seed(57)
grp1=rnorm(50,0,1.5)
grp2=rnorm(50,0.8,3.2)

p = as.vector(BayesFactor::ttestBF(x=grp1,y=grp2,
  posterior = TRUE, iterations = 3000,
  rscale = "medium")[,4])

# flat reference function
res = fbet(p, interval = c(-0.1,0.1), nu=1, FUN=NULL, par=NULL)
show(res)
```

---

show.fbst *show.fbst*

Description

Prints the main results of a Full Bayesian Significance Test to the console.

Usage

```
## S3 method for class 'fbst'
show(object)
```

Arguments

object	An Object of class "fbst".

Details

Shows the main results of a Full Bayesian Significance Test stored in an object of class fbst.

Value

Prints the results onto the console.

Author(s)

Riko Kelter

References

For a details, see: https://arxiv.org/abs/2001.10577 and https://arxiv.org/pdf/2001.10577.pdf.

Examples

```
set.seed(57)
grp1=rnorm(50,0,1.5)
grp2=rnorm(50,0.8,3.2)

p = as.vector(BayesFactor::ttestBF(x=grp1,y=grp2,
  posterior = TRUE, iterations = 3000,
  rscale = "medium")[,4])

# flat reference function
res = fbst(posteriorDensityDraws = p, nullHypothesisValue = 0,
dimensionTheta = 2, dimensionNullset = 1)
show(res)
```

`summary.fbet` *summary.fbet*

Description

Prints the results of a Full Bayesian Evidence Test.

Usage

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

Arguments

`object`	An Object of class `"fbet"`.
`...`	Additional parameters, see `"summary(object,...)"`.

Details

Summarises the results of a Full Bayesian Evidence Test.

Value

Prints the results onto the console.

Author(s)

Riko Kelter

References

For a details, see: https://arxiv.org/abs/2001.10577 and https://arxiv.org/pdf/2001.10577.pdf.

Examples

```
set.seed(57)
grp1=rnorm(50,0,1.5)
grp2=rnorm(50,0.3,3.2)

p = as.vector(BayesFactor::ttestBF(x=grp1,y=grp2,
  posterior = TRUE, iterations = 3000,
  rscale = "medium")[,4])

# flat reference function
res = fbet(p, interval = c(-0.1,0.1), nu=1, FUN=NULL, par=NULL)
summary(res)
```

`summary.fbst` *summary.fbst*

Description

Prints the results of a Full Bayesian Significance Test.

Usage

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

Arguments

`object`	An Object of class `"fbst"`.
`...`	Additional parameters, see `"summary(object,...)"`.

Details

Summarises the results of a Full Bayesian Significance Test.

Value

Prints the results onto the console.

Author(s)

Riko Kelter

References

For a details, see: https://arxiv.org/abs/2001.10577 and https://arxiv.org/pdf/2001.10577.pdf.

Examples

```
set.seed(57)
grp1=rnorm(50,0,1.5)
grp2=rnorm(50,0.8,3.2)

p = as.vector(BayesFactor::ttestBF(x=grp1,y=grp2,
  posterior = TRUE, iterations = 3000,
  rscale = "medium")[,4])

# flat reference function
res = fbst(posteriorDensityDraws = p, nullHypothesisValue = 0,
dimensionTheta = 2, dimensionNullset = 1)
summary(res)
```

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