Package ‘simIReff’

October 14, 2022

Type Package

Title Stochastic Simulation for Information Retrieval Evaluation: Effectiveness Scores

Version 1.0

Description Provides tools for the stochastic simulation of effectiveness scores to mitigate data-related limitations of Information Retrieval evaluation research, as described in Urbano and Nagler (2018) <doi:10.1145/3209978.3210043>. These tools include: fitting, selection and plotting distributions to model system effectiveness, transformation towards a prespecified expected value, proxy to fitting of copula models based on these distributions, and simulation of new evaluation data from these distributions and copula models.

BugReports https://github.com/julian-urbano/simIReff/issues

URL https://github.com/julian-urbano/simIReff/

Depends R (>= 3.4)

Imports stats, graphics, MASS, rvinetopib (>= 0.2.8.1.0), truncnorm, bde, ks, np, extraDistr

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Encoding UTF-8

LazyData true

RoxygenNote 6.0.1

NeedsCompilation no

Author Julián Urbano [aut, cre], Thomas Nagler [ctb]

Maintainer Julián Urbano <urbano.julian@gmail.com>

Repository CRAN

Date/Publication 2018-06-15 15:26:32 UTC
simIReff-package: Stochastic Simulation for Information Retrieval Evaluation: Effectiveness Scores

Description

Provides tools for the stochastic simulation of effectiveness scores to mitigate data-related limitations of Information Retrieval evaluation research. These tools include:

- Fitting of continuous and discrete distributions to model system effectiveness.
- Plotting of effectiveness distributions.
- Selection of distributions best fitting to given data.
- Transformation of distributions towards a prespecified expected value.
- Proxy to fitting of copula models based on these distributions.
- Simulation of new evaluation data from these distributions and copula models.
**Author(s)**

**Maintainer**: Julián Urbano <urbano.julian@gmail.com>

Other contributors:

- Thomas Nagler <thomas.nagler@tum.de> [contributor]

**References**


**See Also**

Useful links:

- https://github.com/julian-urbano/simIReff/
- Report bugs at https://github.com/julian-urbano/simIReff/issues

**Examples**

```r
## Fit a marginal AP distribution and simulate new data
x <- web2010ap[,10] # sample AP scores of a system
e <- effContFitAndSelect(x, method = "BIC") # fit and select based on log-likelihood
plot(e) # plot pdf, cdf and quantile function
e$mean # expected value
y <- reff(50, e) # simulation of 50 new topics

## Transform the distribution to have a pre-specified expected value
e2 <- effTransform(e, mean = .14) # transform for expected value of .14
plot(e2)
e2$mean # check the result

## Build a copula model of two systems
d <- web2010ap[,2:3] # sample AP scores
e1 <- effCont_norm(d[,1]) # force the first margin to follow a truncated gaussian
e2 <- effCont_bks(d[,2]) # force the second margin to follow a beta kernel-smoothed
cop <- effcopFit(d, list(e1, e2)) # copula
y <- reffcop(1000, cop) # simulation of 1000 new topics
c(e1$mean, e2$mean) # expected means
colMeans(y) # observed means

## Modify the model to both systems have the same distribution
cop2 <- cop # copy the model
cop2$margins[[2]] <- e1 # modify 2nd margin
y <- reffcop(1000, cop2) # simulation of 1000 new topics
colMeans(y) # observed means

## Automatically build a gaussian copula to many systems
d <- web2010p20[,1:20] # sample P@20 data from 20 systems
effs <- effDiscFitAndSelect(d, support("p20")) # fit and select margins
```
cop <- effcopFit(d, effs, family_set = "gaussian") # fit copula
y <- reffcop(1000, cop) # simulate new 1000 topics

# compare observed vs. expected mean
E <- sapply(effs, function(e) e$mean)
E.hat <- colMeans(y)
plot(E, E.hat)
abline(0:1)

# compare observed vs. expected variance
Var <- sapply(effs, function(e) e$var)
Var.hat <- apply(y, 2, var)
plot(Var, Var.hat)
abline(0:1)

# compare distributions
o <- order(colMeans(d))
boxplot(d[,o])
points(colMeans(d)[o], col = "red", pch = 4) # plot means
boxplot(y[,o])
points(colMeans(y)[o], col = "red", pch = 4) # plot means

---

**eff**

**Effectiveness Distributions**

**Description**

Density, distribution function, quantile function and random generation for an effectiveness distribution.

**Usage**

- `deff(x, .eff)`
- `peff(q, .eff)`
- `qeff(p, .eff)`
- `reff(n, .eff)`

**Arguments**

- `x, q` vector of quantiles.
- `.eff` the eff object representing the effectiveness distribution.
- `p` vector of probabilities.
- `n` number of observations.
Value
deff gives the density, peff gives the distribution function, qeff gives the quantile function, and reff generates random variates.

See Also
effCont for continuous distributions, and effDisc for discrete distributions.

Examples

# sample distribution from AP scores
e <- effCont_beta(web2010ap[,1])
# pdf integrates to 1
integrate(deff, lower = 0, upper = 1, .eff = e)
# qeff (quantile) is the inverse of peff (cumulative)
qeff(peff(.2, e), e)
# random generation of 100 scores
r <- reff(100, e)

Description

This is the base S3 class for all continuous effectiveness distributions, which is itself a subclass of eff. Function effCont_new is the constructor of the class.

Usage
effCont_new(mean, var, df, x = NULL)

Arguments

mean the expected value of the distribution.
var the variance of the distribution.
df the effective degrees of freedom of the distribution.
x the sample of effectiveness scores used to fit the distribution. Defaults to NULL.

Details

A new distribution family is expected to build new objects through this constructor, and they must implement methods deff, peff, qeff and reff.
Value

an object of class `eff.cont`, with the following components:

- **mean**: the expected value.
- **var**: the variance.
- **df**: the degrees of freedom (effective number of parameters) for model selection.
- **data**: the sample data used to fit the distribution, or `NULL` if none.
- **model**: a list with the family-specific data.

See Also

effCont for a list of currently implemented distribution families, effContFit to fit distributions, and effCont-helper for helper functions.

For discrete distributions, see eff.disc.

---

eff.disc-class

Class `eff.disc`

Description

This is the base S3 class for all discrete effectiveness distributions, which is itself a subclass of `eff`. Function `effDisc_new` is the constructor of the class.

Usage

effDisc_new(p, support, df, x = NULL)

Arguments

- **p**: the values of the distribution function at the support points.
- **support**: the support of the distribution.
- **df**: the effective degrees of freedom of the distribution.
- **x**: the sample of effectiveness scores used to fit the distribution. Defaults to `NULL`.

Details

A new distribution family is expected to build new objects through this constructor. Default implementations are readily available for methods `deff`, `peff`, `qeff` and `reff`.
Value

an object of class `eff.disc`, with the following components:

- **mean**: the expected value.
- **var**: the variance.
- **df**: the degrees of freedom (effective number of parameters) for model selection.
- **support**: the support of the distribution.
- **data**: the sample data used to fit the distribution, or `NULL` if none.
- **model**: a list with the family-specific data.

See Also

effDisc for a list of currently implemented distribution families, effDiscFit to fit distributions, and effDisc-helper for helper functions.

For continuous distributions, see eff.cont.

---

effCont

Continuous Effectiveness Distributions

Description

Families to model effectiveness distributions with continuous support. Currently implemented families are:

- `effCont_norm` Truncated Normal.
- `effCont_beta` Beta.
- `effCont_nks` Truncated Kernel-smoothed with Gaussian kernel.
- `effCont_bks` Kernel-smoothed with Beta kernel.

See Also

effContFit to fit continuous distributions, and eff.cont for the S3 class.

For discrete distributions, see effDisc.

---

effCont-helper

Helper functions for continuous effectiveness distributions

Description

These are functions to help in the creation and use of continuous effectiveness distributions.
Usage

cap(x, xmin = 1e-06, xmax = 1 - xmin)

effContMean(qfun, abs.tol = 1e-06, subdivisions = 500)

effContVar(qfun, mu, abs.tol = 1e-06, subdivisions = 500)

effContTrunc(dfun, pfun, qfun, ...)

Arguments

x a sample of effectiveness scores.
 xmin lowest value to cap scores.
 xmax highest value to cap scores.
 qfun a quantile function.
 abs.tol absolute accuracy requested, passed to integrate.
 subdivisions the maximum number of subintervals, passed to integrate.
 mu the expected value of the distribution (see effContMean).
 dfun a density function.
 pfun a distribution function.
 ... additional arguments passed to other functions, if any.

Details

cap caps (censor) a variable from below and above.
effContMean computes the expected value of a distribution by numerical integration of the given quantile function.
effContVar computes the variance of a distribution by numerical integration of the given quantile function.
effContTrunc computes the density, distribution and quantile functions of the distribution resulting from truncating a given distribution between 0 and 1.

Value

cap: the original vector, but censored.
effContMean: the estimate of the expected value.
effContVar: the estimate of the variance.
effContTrunc: a list with components:

    td  the truncated density function.
    tp  the truncated distribution function.
    tq  the truncated quantile function.
See Also
eff.cont.

Examples
cap(c(0, .5, 1))
effContMean(function(p) qnorm(p, mean = 4))
effContMean(function(p) qbeta(p, 1, 2))

effContVar(function(p) qnorm(p, mean = 2, sd = 4), 2)
effContVar(function(p) qbeta(p, 1, 2), 1/3)

tr <- effContTrunc(dnorm, pnorm, qnorm, mean = .8, sd = .3)
x01 <- seq(0, 1, .01)
plot(x01, tr$d(x01), type = "l")
plot(x01, tr$p(x01), type = "l")
plot(x01, tr$q(x01), type = "l")

---

effCont_beta  
Continuous Effectiveness as Beta Distribution.

Description
Fits a Beta distribution to the given sample of scores.

Usage
effCont_beta(x)

Arguments

x  
a sample of effectiveness scores between 0 and 1.

Value
an object of class eff.cont.beta, which inherits from eff.cont.

See Also
deff, peff, qeff and reff.

Examples
e <- effCont_beta(web2010ap[,1])
c(e$mean, e$var)
plot(e, plot.data = TRUE)
effCont_bks

Description
Fits a bounded kernel-smoothed distribution to the given sample of scores. In particular, the beta kernel by Chen (1999) is used, as in Chen99Kernel.

Usage
effCont_bks(x)

Arguments
x a sample of effectiveness scores between 0 and 1.

Value
an object of class eff.cont.bks, which inherits from eff.cont.

References

See Also
deff, peff, qeff and reff.

Examples
e <- effCont_bks(web2010ap[,1])
c(e$mean, e$var)
plot(e, plot.data = TRUE)

effCont_nks

Description
Fits a kernel-smoothed distribution to the given sample of scores, truncated between 0 and 1, and using a gaussian kernel.

Usage
effCont_nks(x)
Arguments

x a sample of effectiveness scores between 0 and 1.

Value

an object of class eff.cont.nks, which inherits from eff.cont.

See Also
deff, peff, qeff and reff.

Examples

e <- effCont_nks(web2010ap[,1])
c(e$mean, e$var)
plot(e, plot.data = TRUE)
Fit Vine copula models to matrices of effectiveness scores

Description

Fitting of and simulation from a copula model.

Usage

effcopFit(x, eff, ...)

reffcop(n, .effcop)

Arguments

x a matrix or data frame of effectiveness scores to estimate dependence.

eff a list of effectiveness distributions to use for the margins.

... other parameters for vinecop, such as family_set, selcrit, trunc_lvl and cores.

n number of observations to simulate.

.effcop the effcop object representing the copula model (see effcopFit).

Value

effcopFit: an object of class effcop, with the following components:

data the matrix of effectiveness scores used to fit the copula.

pobs the matrix of pseudo-observations computed from data. This is stored because pseudo-observations are calculated breaking ties randomly (see pseudo_obs).

margins the list of marginal effectiveness distributions.

cop the underlying copulas fitted with vinecop.

These components may be altered to gain specific simulation capacity, such as systems with the same expected value.

reffcop: a matrix of random scores.

See Also

effCont and effDisc for available distributions for the margins. See package rvinecopulib for details on fitting the copulas.

Examples

## Automatically build a gaussian copula to many systems
d <- web2010p20[,1:20] # sample P@20 data from 20 systems
effs <- effDiscFitAndSelect(d, support("p20")) # fit and select margins
cop <- effcopFit(d, effs, family_set = "gaussian") # fit copula
y <- reffcop(1000, cop) # simulate new 1000 topics

# compare observed vs. expected mean
E <- sapply(effs, function(e) e$mean)
E.hat <- colMeans(y)
plot(E, E.hat)
abline(0:1)

# compare observed vs. expected variance
Var <- sapply(effs, function(e) e$var)
Var.hat <- apply(y, 2, var)
plot(Var, Var.hat)
abline(0:1)

disc <- fitcpl(d, effs, family_set = "gaussian") # fit copula
fitcpl(1000, disc) # simulate new 1000 topics

# compare observed vs. expected mean
E <- sapply(effs, function(e) e$mean)
E.hat <- colMeans(y)
plot(E, E.hat)
abline(0:1)

# compare observed vs. expected variance
Var <- sapply(effs, function(e) e$var)
Var.hat <- apply(y, 2, var)
plot(Var, Var.hat)
abline(0:1)

effDisc  
Discrete Effectiveness Distributions

Description
Families to model effectiveness distributions with discrete support. Currently implemented families are:

- effDisc_bbinom  Beta-Binomial
- effDisc_dks  Kernel-smoothed with Discrete kernel.

See Also
effDiscFit to fit discrete distributions, and eff.disc for the S3 class. For continuous distributions, see effCont.

effDisc-helper  
Helper functions for discrete effectiveness distributions

Description
These are functions to help in the creation and use of discrete effectiveness distributions.

Usage
matchTol(x, support, tol = 1e-04)
support(measure, runLength = 1000)
**Arguments**

- **x**: a vector of effectiveness scores.
- **support**: the support of the distribution.
- **tol**: tolerance for matching.
- **measure**: the case insensitive name of the effectiveness measure. See Details.
- **runLength**: the maximum number of documents retrieved for a query (defaults to 1000).

**Details**

- **matchTol**: returns a vector of the positions of matches of `x` in the vector of possible support values, within tolerance (see `match`). This is helpful when data are loaded from disk and possibly rounded or truncated.
- **support**: obtains the discrete support defined by an effectiveness measure given its name. Current measures are Reciprocal Rank ("RR"), and Precision at k ("P@k" or "Pk", where k is the cutoff, eg. "P@10" or "P10").

**Value**

- **matchTol**: an integer vector giving the position in the support of the match if there is a match, otherwise NA.
- **support**: the support of the distribution of scores defined by the measure.

**See Also**

- [eff.disc](#).

**Examples**

```r
support("rr")
support("rr", runLength = 10)
support("p@10")
support("P@10")

(i <- matchTol(c(.1, .4, .41, .40001), support("P@10")))
support("P@10"))[i]
```

---

**effDisc_bbinom**

*Discrete Effectiveness as Beta-Binomial Distribution.*

**Description**

Fits a discrete kernel-smoothed distribution, to the given sample of scores and support points.

**Usage**

```r
effDisc_bbinom(x, support)
```
**Arguments**

- \( x \) a sample of effectiveness scores between 0 and 1.
- \( \text{support} \) the support of the distribution.

**Value**

an object of class `eff.disc.bbinom`, which inherits from `eff.disc`.

**See Also**

deff, peff, qeff and reff.

**Examples**

```r
e <- effDisc_bbinom(web2010p20[,1], seq(0,1,.05))
c(e$mean, e$var)
plot(e, plot.data = TRUE)
```

---

**Description**

Fits a Beta-Binomial distribution, to the given sample of scores and support points.

**Usage**

effDisc_dks(x, support, mult = 1)

**Arguments**

- \( x \) a sample of effectiveness scores between 0 and 1.
- \( \text{support} \) the support of the distribution.
- \( \text{mult} \) a constant to multiply the initially selected bandwidth.

**Value**

an object of class `eff.disc.dks`, which inherits from `eff.disc`.

**References**


**See Also**

deff, peff, qeff and reff.
Examples

```r
e <- effDisc_dks(web2010p20[,1], seq(0,1,.05))
c(e$mean, e$var)
plot(e, plot.data = TRUE)
e2 <- effDisc_dks(web2010p20[,1], seq(0,1,.05), mult = 2)
c(e2$mean, e2$var)
plot(e2, plot.data = TRUE)
```

**effFit**

*Fit Effectiveness Distributions*

**Description**

Attempts to fit the distribution families listed in *effCont* or *effDisc*. In the discrete case, the *dks* distribution is fitted with multipliers 1, 2, 5 and 10. Failure to fit any distribution family results in an error.

**Usage**

```r
effContFit(x, silent = TRUE)
effDiscFit(x, support, silent = TRUE)
```

**Arguments**

- `x`  
a sample of effectiveness scores between 0 and 1.
- `silent`  
logical: should the report of error messages be suppressed?
- `support`  
the support of the distribution (see `support`).

**Value**

a list of *eff.cont* objects fitted to the given data.

**See Also**

*effCont* and *effDisc* for the available distribution families.

See *effSelect* for model selection, and *effFitAndSelect* to fit and select automatically.

**Examples**

```r
e <- effContFit(web2010p20[,1])
str(e, 1)
sapply(e, plot, plot.data = TRUE)
e <- effDiscFit(web2010p20[,1], seq(0,1,.05))
str(e, 1)
sapply(e, plot, plot.data = TRUE)
```
effFitAndSelect

Automatic Fitting and Selection of Effectiveness Distributions

Description

Automatic Fitting and Selection of Effectiveness Distributions

Usage

effContFitAndSelect(x, method = "AIC", silent = TRUE)

effDiscFitAndSelect(x, support, method = "AIC", silent = TRUE)

Arguments

- x: a sample of effectiveness scores between 0 and 1, or a matrix or data frame of topic-by-system scores.
- method: selection method. See effSelect.
- silent: logical: should the report of error messages be suppressed?
- support: the support of the distribution (see support).

Value

if x is a vector, the selected distribution. If x is a matrix or data frame, a list of the selected distributions.

See Also

effFit and effSelect.

Examples

e <- effContFitAndSelect(web2010ap[,1], method = "logLik")
c(e$mean, e$var)
e2 <- effContFitAndSelect(web2010ap[,2], method = "logLik")
c(e2$mean, e2$var)

e <- effContFitAndSelect(web2010ap[,1:2], method = "logLik")
sapply(ee, function(e) c(e$mean, e$var)) # same as above
Description

Functions to compute the log-likelihood, the Akaike Information Criterion, and the Bayesian Information Criterion for an effectiveness distribution. `effSelect` and `which.effSelect` are helper function for automatic selection from a given list of candidates.

Usage

```r
effSelect(effs, method = "AIC", ...) 
which.effSelect(effs, method = "AIC", ...)
## S3 method for class 'eff'
logLik(object, ...)
```

Arguments

- `effs`: the list of candidate distributions to select from.
- `method`: selection method. One of "AIC" (default), "BIC", or "logLik".
- `...`: other parameters to the selection function.
- `object`: an effectiveness distribution.

Value

the selected distribution (`effSelect`), or its index within `effs` (`which.effSelect`).

See Also

`logLik`, `AIC`, `BIC` for details on model selection.

See `effFitAndSelect` to fit and select automatically.

Examples

```r
ee <- effContFit(web2010ap[,5])
e <- effSelect(ee, method = "BIC")
e2 <- ee[[which.effSelect(ee, method = "BIC")]] # same as e

logLik(e)
AIC(e, k=4)
BIC(e)
```
**effTransform**

**Transform effectiveness distributions towards a expected value**

**Description**

Transforms the given effectiveness distribution such that its expected value matches a predefined value. For details, please refer to section 3.4 of (Urbano and Nagler, 2018).

**Usage**

```r
effTransform(eff, mean, abs.tol = 1e-05)
effTransformAll(effs, means, abs.tol = 1e-05, silent = TRUE)
```

**Arguments**

- `eff`: the distribution to transform.
- `mean`: the target expected value to transform to. If missing, defaults to the mean in the data used to fit `eff`, if any.
- `abs.tol`: the absolute tolerance of the transformation.
- `effs`: the list of distributions to transform.
- `means`: the vector of target expected values to transform to. If missing, defaults to the means in the data used to fit `effs`, if any.
- `silent`: logical: should the report of error messages be suppressed?

**Details**

`effTransformAll` does the same but for a list of distributions and target means.

**Value**

An effectiveness distribution of class `eff.cont.trans` or `eff.disc.trans`, depending on the type of distribution.

**References**


**Examples**

```r
e <- effCont_beta(web2010ap[,1])
e2 <- effTransform(e, 0.12)
c(e$mean, e2$mean)
plot(e)
plot(e2)
```
# transform a list of distributions to the observed means
ee <- effContFitAndSelect(web2010ap[,1:5])
e2 <- effTransformAll(ee)
obsmeans <- colMeans(web2010ap[,1:5])
sapply(ee, function(e)e$mean) - obsmeans
sapply(e2, function(e)e$mean) - obsmeans

---

**plot.eff**

*Plotting tools for effectiveness distributions*

**Description**

Plot the density, distribution and quantile functions of an effectiveness distribution. Function plot plots all three functions in the same graphics device.

**Usage**

```r
## S3 method for class 'eff'
plot(x, ..., plot.data = TRUE)
dplot(x, ..., plot.data = TRUE)
pplot(x, ..., plot.data = TRUE)
qplot(x, ..., plot.data = TRUE)
```

**Arguments**

- `x` the effectiveness distribution to plot.
- `...` other arguments to be passed to graphical functions.
- `plot.data` logical: whether to plot the data used to fit the distribution, if any.

**See Also**

`plot.eff.cont` and `plot.eff.disc` for more details.
Plotting tools for Continuous effectiveness distributions

Description

Plot the density, distribution and quantile functions of a continuous effectiveness distribution.

Usage

```r
## S3 method for class 'eff.cont'
dplot(x, ..., plot.data = TRUE, subdivisions = 200,
     xlab = "x", ylab = "f(x)", main = "density")

## S3 method for class 'eff.cont'
pplot(x, ..., plot.data = TRUE, subdivisions = 200,
     xlab = "q", ylab = "F(q)", main = "distribution")

## S3 method for class 'eff.cont'
qplot(x, ..., plot.data = TRUE, subdivisions = 200,
     xlab = "p", ylab = expression(F^-1 * (p)), main = "quantile")
```

Arguments

- `x`: the effectiveness distribution to plot.
- `...`: arguments to be passed to `lines`.
- `plot.data`: logical: whether to plot the data used to fit the distribution, if any.
- `subdivisions`: number of equidistant points at which to evaluate the distribution to plot.
- `xlab`: the title for the x axis.
- `ylab`: the title for the y axis.
- `main`: the overall title for the plot.

See Also

`plot.eff.disc` for discrete distributions.

Plotting tools for Discrete effectiveness distributions

Description

Plot the density, distribution and quantile functions of a discrete effectiveness distribution.
Usage

```r
## S3 method for class 'eff.disc'
dplot(x, ..., plot.data = TRUE, xlab = "x",
      ylab = "f(x)", main = "mass")
## S3 method for class 'eff.disc'
pplot(x, ..., plot.data = TRUE, xlab = "q",
      ylab = "F(q)", main = "distribution")
## S3 method for class 'eff.disc'
qplot(x, ..., plot.data = TRUE, xlab = "p",
      ylab = expression(F^{-1} * (p)), main = "quantile")
```

Arguments

- `x`: the effectiveness distribution to plot.
- `...`: arguments to be passed to `lines`.
- `plot.data`: logical: whether to plot the data used to fit the distribution, if any.
- `xlab`: the title for the x axis.
- `ylab`: the title for the y axis.
- `main`: the overall title for the plot.

See Also

- `plot.eff.cont` for continuous distributions.

Description

These are the topic-by-system effectiveness matrices for the 88 systems submitted to the TREC 2010 Web Ad hoc track, evaluated over 48 topics. `web2010ap` contains Average Precision scores, `web2010p20` contains Precision at 20 scores, and `web2010rr` contains Reciprocal Rank scores.

Format

A data frame with 88 columns (systems) and 48 rows (queries).
References


See Also

https://trec.nist.gov
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