

Package ‘melt’

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Type Package

Title Multiple Empirical Likelihood Tests

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Description Performs multiple empirical likelihood tests for linear and generalized linear models. The package offers an easy-to-use interface and flexibility in specifying hypotheses and calibration methods, extending the framework to simultaneous inferences. The core computational routines are implemented using the 'Eigen' C++ library and 'RcppEigen' interface, with OpenMP for parallel computation. Details of the testing procedures are given in Kim, MacEachern, and Peruggia (2021) <[arxiv:2112.09206](https://arxiv.org/abs/2112.09206)>. This work was supported by the U.S. National Science Foundation under Grants No. SES-1921523 and DMS-2015552.

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CEL-class *CEL class*

Description

S4 class for constrained empirical likelihood. It inherits from [EL](#) class. Note that the ‘optim’ slot has constrained optimization results with respect to the parameters, not the Lagrange multiplier.

Details

Let $l(\theta)$ denote minus twice the empirical log-likelihood ratio function. We consider a linear hypothesis of the form

$$L\theta = r,$$

where the left-hand-side L is a q by p matrix and the right-hand-side r is a q -dimensional vector. Under some regularity conditions, $l(\theta)$ converges in distribution to χ_q^2 under the constraint of hypothesis, i.e.,

$$\min_{\theta: L\theta=r} l(\theta) \rightarrow_d \chi_q^2.$$

Minimization of $l(\theta)$ with respect to θ is computationally expensive since it implicitly involves the evaluation step as described in [EL](#). Further, depending on the form of $g(X_i, \theta)$ and the constraint, the optimization problem can be nonconvex and have multiple local minima. For this reason, the package **melt** only considers linear hypotheses and performs local minimization of $l(\theta)$ using projected gradient descent method. With the orthogonal projection matrix P and a step size γ , the algorithm updates θ as

$$\theta^{(k+1)} \leftarrow \theta^{(k)} - \gamma P \nabla l(\theta^{(k)}),$$

where $\nabla l(\theta^{(k)})$ denotes the gradient of l at $\theta^{(k)}$. The first order optimality condition is $P \nabla l(\theta) = 0$, which is used as the stopping criterion.

Slots

optim A list of the following optimization results: * ‘par’ A numeric vector of the solution to the constrained optimization problem. * ‘lambda’ A numeric vector of the Lagrange multipliers of the dual problem corresponding to ‘par’. * ‘iterations’ A single integer for the number of iterations performed. * ‘convergence’ A single logical for the convergence status.

logp A numeric vector of the log probabilities of the constrained empirical likelihood.

logl A single numeric of the constrained empirical log-likelihood.

loglr A single numeric of the constrained empirical log-likelihood ratio.

statistic A single numeric of minus twice the constrained empirical log-likelihood ratio with an asymptotic chi-square distribution.

df A single integer for the degrees of freedom of the statistic.

pval A single numeric for the p -value of the statistic.

nobs A single integer for the number of observations.

npar A single integer for the number of parameters.

weights A numeric vector of the re-scaled weights used for the model fitting.

coefficients A numeric vector of the maximum empirical likelihood estimates of the parameters.

method A single character for the method dispatch in internal functions.

data A numeric matrix of the data for the model fitting.

References

Adimari G, Guolo A (2010). "A Note on the Asymptotic Behaviour of Empirical Likelihood Statistics." *Statistical Methods & Applications*, 19(4), 463–476. doi:10.1007/s1026001001379.

Qin J, Lawless J (1995). "Estimating Equations, Empirical Likelihood and Constraints on Parameters." *Canadian Journal of Statistics*, 23(2), 145–159. doi:10.2307/3315441.

Examples

```
showClass("CEL")
```

chisq	<i>Chi-square statistic</i>
-------	-----------------------------

Description

Extracts chi-square statistic from a model.

Usage

```
## S4 method for signature 'EL'
chisq(object, ...)

## S4 method for signature 'ELMT'
chisq(object, ...)

## S4 method for signature 'ELT'
chisq(object, ...)

## S4 method for signature 'SummaryLM'
chisq(object, ...)
```

Arguments

`object` An object that inherits from [EL](#), [ELT](#), [ELMT](#), or [SummaryLM](#).
`...` Further arguments passed to methods.

Value

The form of the value returned by `[chisq()]` depends on the class of its argument.

Methods (by class)

- `chisq(EL)`: Extracts the chi-square statistic.
- `chisq(ELMT)`: Extracts the vector of chi-square statistics.
- `chisq(ELT)`: Extracts the chi-square statistic.
- `chisq(SummaryLM)`: Extracts the chi-square statistic for the overall test of the model.

See Also

[EL](#), [ELT](#), [ELMT](#), [SummaryLM](#), `[pVal()]`

Examples

```
data("precip")
fit <- el_mean(precip, par = 40)
chisq(fit)
```

clothianidin

Clothianidin concentration in maize plants

Description

A dataset summarizing field experiments result of seed treatments on clothianidin concentration.

Usage

```
data("clothianidin")
```

Format

A data frame with 102 observations and 3 variables:

blk New blocks constructed from original data. The format is 'days post planting_original block_year'.

trt Seed treatment.

clo Log transformed clothianidin concentration (μg).

Details

The original data is provided by Alford and Krupke (2017). Only some of the shoot region observations are taken from the original data and processed for illustration.

Source

Alford A, Krupke CH (2017). “Translocation of the Neonicotinoid Seed Treatment Clothianidin in Maize.” *PLOS ONE*, 12(3), 1–19. doi:10.1371/journal.pone.0173836.

Examples

```
data("clothianidin")
clothianidin
```

coef	<i>Model coefficients</i>
------	---------------------------

Description

Extracts maximum empirical likelihood estimates from a model.

Usage

```
## S4 method for signature 'EL'
coef(object, ...)

## S4 method for signature 'ELMT'
coef(object, ...)
```

Arguments

object	An object that inherits from EL or ELMT .
...	Further arguments passed to methods.

Value

The form of the value returned by [coef()] depends on the class of its argument.

Methods (by class)

- coef(EL): Extracts the numeric vector of the maximum empirical likelihood estimates.
- coef(ELMT): Extracts the list of numeric vectors of the maximum empirical likelihood estimates. Each element of the list corresponds to a distinct hypothesis.

See Also

[EL](#), [ELMT](#)

Examples

```
data("mtcars")
fit <- el_lm(mpg ~ wt, data = mtcars)
coef(fit)
```

 confint

Confidence interval for model parameters

Description

Computes confidence intervals for one or more parameters in a model.

Usage

```
## S4 method for signature 'EL'
confint(object, parm, level = 0.95, cv = NULL, control = el_control())
```

Arguments

object	An object that inherits from EL .
parm	A specification of which parameters are to be given confidence intervals, either a vector of numbers or a vector of names. If missing, all parameters are considered.
level	A single numeric for the confidence level required. Defaults to '0.95'.
cv	A single numeric for the critical value for calibration of empirical likelihood ratio statistic. Defaults to 'NULL' and set to 'qchisq(level, 1L)'. If non-'NULL', 'level' is ignored.
control	An object of class ControlEL constructed by [el_control()].

Value

A matrix with columns giving lower and upper confidence limits for each parameter. In contrast to other methods that rely on studentization, the lower and upper limits obtained from empirical likelihood do not correspond to the $(1 - \text{level}) / 2$ and $1 - (1 - \text{level}) / 2$ in respectively.

References

Owen A (1990). "Empirical Likelihood Ratio Confidence Regions." *The Annals of Statistics*, 18(1), 90–120. doi:10.1214/aos/1176347494.

See Also

[confreg()], [elt()], [el_control()]

Examples

```
data("mtcars")
fit <- el_lm(mpg ~ ., data = mtcars)
confint(fit, parm = c(2, 3))
```

 confreg

Confidence region for model parameters

Description

Computes boundary points of a two-dimensional confidence region for model parameters.

Usage

```
## S4 method for signature 'EL'
confreg(
  object,
  parm,
  level = 0.95,
  cv = NULL,
  npoints = 50L,
  control = el_control()
)
```

Arguments

object	An object that inherits from EL .
parm	A specification of which parameters are to be given a confidence region, either a vector of numbers or a vector of names. It must be a vector of length two of the form 'c(x, y)'. If missing, the first two parameter in 'object' are considered.
level	A single numeric for the confidence level required. Defaults to '0.95'. It is ignored if 'cv' is non-'NULL'.
cv	A single numeric for the critical value for calibration of empirical likelihood ratio statistic. Defaults to NULL and set to 'qchisq(level, 2L)'. It must be compatible with the 'th' value in 'control'.
npoints	A single integer for the number of boundary points to compute. Defaults to '50'.
control	An object of class ControlEL constructed by [el_control()].

Value

An object of class [ConfregEL](#).

References

Owen A (1990). "Empirical Likelihood Ratio Confidence Regions." *The Annals of Statistics*, 18(1), 90–120. doi:10.1214/aos/1176347494.

See Also

[confint()], [elt()], [plot()], [el_control()]

Examples

```
data("mtcars")
fit <- el_lm(mpg ~ wt + qsec, data = mtcars)
cr <- confreg(fit, parm = c(2, 3), cv = qchisq(0.90, 2))
plot(cr)
```

ConfregEL-class *ConfregEL class*

Description

S4 class for confidence region. It inherits from "matrix".

Slots

`estimates` A numeric vector of length two for the parameter estimates.

`level` A single numeric for the confidence level required.

`cv` A single numeric for the critical value for calibration of empirical likelihood ratio statistic.

`pnames` A character vector of length two for the name of parameters.

Examples

```
showClass("ConfregEL")
```

ControlEL-class *ControlEL class*

Description

S4 class for computational details of empirical likelihood.

Slots

`maxit` A single integer for the maximum number of iterations for the optimization with respect to θ .

`maxit_l` A single integer for the maximum number of iterations for the optimization with respect to λ .

`tol` A single numeric for the convergence tolerance denoted by ϵ . The iteration stops when

$$\|P\nabla l(\theta^{(k)})\| < \epsilon.$$

tol_1 A single numeric for the relative convergence tolerance denoted by δ . The iteration stops when

$$\|\lambda^{(k)} - \lambda^{(k-1)}\| < \delta \|\lambda^{(k-1)}\| + \delta^2.$$

step A single numeric for the step size γ for the projected gradient descent method.

th A single numeric for the threshold for the negative empirical log-likelihood ratio.

verbose A single logical for whether to print a message on the convergence status.

keep_data A single logical for whether to

nthreads A single integer for the number of threads for parallel computation via OpenMP (if available).

seed A single integer for the seed for random number generation.

b A single integer for the number of bootstrap replicates.

m A single integer for the number of Monte Carlo samples.

Examples

```
showClass("ControlEL")
```

conv

Convergence check

Description

Extracts convergence status from a model.

Usage

```
## S4 method for signature 'CEL'
conv(object, ...)
```

```
## S4 method for signature 'EL'
conv(object, ...)
```

```
## S4 method for signature 'ELT'
conv(object, ...)
```

```
## S4 method for signature 'SummaryLM'
conv(object, ...)
```

Arguments

object An object that inherits from [EL](#), [SummaryLM](#), or [ELT](#).
 ... Further arguments passed to methods.

Value

A single logical.

Methods (by class)

- `conv(CEL)`: Extracts the convergence status of the model with respect to the parameter.
- `conv(EL)`: Extracts the convergence status of the model with respect to the Lagrange multiplier.
- `conv(ELT)`: Extracts the convergence status of the model with respect to the parameter (or the Lagrange multiplier if 'lhs' is 'NULL').
- `conv(SummaryLM)`: Extracts the convergence status of the model. See the documentation of [EL](#) and [CEL](#).

See Also

[EL](#), [ELT](#), [SummaryLM](#)

Examples

```
## Convergence check for the overall model test
data("mtcars")
fit <- el_lm(mpg ~ ., data = mtcars)
conv(fit)
```

critVal

Critical value

Description

Extracts critical value from a model.

Usage

```
## S4 method for signature 'ELT'
critVal(object, ...)

## S4 method for signature 'ELMT'
critVal(object, ...)
```

Arguments

`object` An object that inherits from [ELT](#) or [ELMT](#).
`...` Further arguments passed to methods.

Value

A single numeric.

See Also[ELT](#), [ELMT](#)**Examples**

```
## F-calibrated critical value
data("precip")
fit <- el_mean(precip, 30)
elt <- elt(fit, rhs = 34, calibrate = "f")
critVal(elt)
```

EL-class

*EL class***Description**

S4 class for empirical likelihood.

Details

Let X_i be independent and identically distributed p -dimensional random variable from an unknown distribution P for $i = 1, \dots, n$. We assume that P has a positive definite covariance matrix. For a parameter of interest $\theta(F) \in \mathbb{R}^p$, consider a p -dimensional smooth estimating function $g(X_i, \theta)$ with a moment condition

$$E[g(X_i, \theta)] = 0.$$

We assume that there exists a unique θ_0 that solves the above equation. Given a value of θ , the (profile) empirical likelihood ratio is defined by

$$R(\theta) = \max_{p_i} \left\{ \prod_{i=1}^n np_i : \sum_{i=1}^n p_i g(X_i, \theta) = 0, p_i \geq 0, \sum_{i=1}^n p_i = 1 \right\}.$$

The Lagrange multiplier $\lambda \equiv \lambda(\theta)$ of the dual problem leads to

$$p_i = \frac{1}{n} \frac{1}{1 + \lambda^\top g(X_i, \theta)},$$

where λ solves

$$\frac{1}{n} \sum_{i=1}^n \frac{g(X_i, \theta)}{1 + \lambda^\top g(X_i, \theta)} = 0.$$

Then the empirical log-likelihood ratio is given by

$$\log R(\theta) = - \sum_{i=1}^n \log(1 + \lambda^\top g(X_i, \theta)).$$

This problem can be efficiently solved by the Newton-Raphson method when the zero vector is contained in the interior of the convex hull of $\{g(X_i, \theta)\}_{i=1}^n$.

It is known that $-2 \log R(\theta_0)$ converges in distribution to χ_p^2 , where χ_p^2 has a chi-square distribution with p degrees of freedom. See the references below for more details.

Slots

`optim` A list of the following optimization results: * `'par'` A numeric vector of the solution to the optimization problem. * `'lambda'` A numeric vector of the Lagrange multipliers of the dual problem corresponding to `'par'`. * `'iterations'` A single integer for the number of iterations performed. * `'convergence'` A single logical for the convergence status.

`logp` A numeric vector of the log probabilities of the empirical likelihood.

`logl` A single numeric of the empirical log-likelihood.

`loglr` A single numeric of the empirical log-likelihood ratio.

`statistic` A single numeric of minus twice the empirical log-likelihood ratio with an asymptotic chi-square distribution.

`df` A single integer for the degrees of freedom of the statistic.

`pval` A single numeric for the p -value of the statistic.

`nobs` A single integer for the number of observations.

`npar` A single integer for the number of parameters.

`weights` A numeric vector of the re-scaled weights used for the model fitting.

`coefficients` A numeric vector of the maximum empirical likelihood estimates of the parameters.

`method` A single character for the method dispatch in internal functions.

`data` A numeric matrix of the data for the model fitting.

References

Owen A (2001). *Empirical Likelihood*. Chapman & Hall/CRC. doi:10.1201/9781420036152.

Qin J, Lawless J (1994). "Empirical Likelihood and General Estimating Equations." *The Annals of Statistics*, 22(1), 300–325. doi:10.1214/aos/1176325370.

Examples

```
showClass("EL")
```

eld *Empirical likelihood displacement*

Description

Computes empirical likelihood displacement for model diagnostics and outlier detection.

Usage

```
## S4 method for signature 'EL'
eld(object, control = el_control())

## S4 method for signature 'GLM'
eld(object, control = el_control())
```

Arguments

object	An object that inherits from EL .
control	An object of class ControlEL constructed by <code>[el_control()]</code> .

Details

Let $L(\theta)$ be the empirical log-likelihood function based on the full sample with n observations. The maximum empirical likelihood estimate is denoted by $\hat{\theta}$. Consider a reduced sample with the i th observation deleted and the corresponding estimate $\hat{\theta}_{(i)}$. The empirical likelihood displacement is defined by

$$\text{ELD}_i = 2\{L(\hat{\theta}) - L(\hat{\theta}_{(i)})\}.$$

If ELD_i is large, then the i th observation is an influential point and can be inspected as a possible outlier. ‘eld’ computes ELD_i for $i = 1, \dots, n$.

Value

An object of class [ELD](#).

References

Lazar NA (2005). “Assessing the Effect of Individual Data Points on Inference From Empirical Likelihood.” *Journal of Computational and Graphical Statistics*, 14(3), 626–642. doi:10.1198/106186005X59568.

Zhu H, Ibrahim JG, Tang N, Zhang H (2008). “Diagnostic Measures for Empirical Likelihood of General Estimating Equations.” *Biometrika*, 95(2), 489–507. doi:10.1093/biomet/asm094.

See Also

[ELD](#), `[plot()]`, `[el_control()]`

Examples

```
data("precip")
fit <- el_mean(precip, par = 30)
eld <- eld(fit)
plot(eld)
```

ELD-class

ELD class

Description

S4 class for empirical likelihood displacement. It inherits from “numeric”.

Examples

```
showClass("ELD")
```

elmt *Empirical likelihood multiple tests*

Description

Tests multiple linear hypotheses simultaneously.

Usage

```
## S4 method for signature 'EL'
elmt(object, rhs = NULL, lhs = NULL, alpha = 0.05, control = el_control())
```

Arguments

object	An object that inherits from EL .
rhs	A numeric vector (column matrix) or a list of numeric vectors for the right-hand sides of hypotheses. Defaults to 'NULL'. See 'Details'.
lhs	A list or a numeric matrix for the left-hand sides of hypotheses. For a list 'lhs', each element must be specified as a single instance of the 'lhs' in [elt()]. For a matrix 'lhs', each row gives a linear combination of the parameters in 'object'. The number of columns must be equal to the number of parameters. Defaults to 'NULL'. See 'Details'.
alpha	A single numeric for the overall significance level. Defaults to '0.05'.
control	An object of class ControlEL constructed by [el_control()].

Details

[elmt()] tests multiple hypotheses simultaneously. Each hypothesis corresponds to the constrained empirical likelihood ratio described in [CEL](#). 'rhs' and 'lhs' cannot be both 'NULL'. The right-hand side and left-hand side of each hypothesis must be specified as described in [elt()].

For specifying linear contrasts more conveniently, 'rhs' and 'lhs' also take a numeric vector and a numeric matrix, respectively. Each element of 'rhs' and each row of 'lhs' correspond to a contrast (hypothesis).

The vector of empirical likelihood ratio statistics asymptotically follows a multivariate chi-square distribution under the complete null hypothesis. The multiple testing procedure asymptotically controls the family-wise error rate at the level 'alpha'. Based on the distribution of the maximum of the test statistics, the adjusted p-values are estimated by Monte Carlo simulation.

Value

An object of class of [ELMT](#).

References

Kim E, MacEachern S, Peruggia M (2021). "Empirical Likelihood for the Analysis of Experimental Designs." arxiv:2112.09206. URL <<https://arxiv.org/abs/2112.09206>>.

See Also

[ELMT](#), `[elt()]`, `[el_control()]`

Examples

```
## Bivariate mean (list `rhs` & no `lhs`)
set.seed(143)
data("women")
fit <- el_mean(women, par = c(65, 135))
rhs <- list(c(64, 133), c(66, 140))
elmt(fit, rhs = rhs)

## Pairwise comparison (no `rhs` & list `lhs`)
data("clothianidin")
fit2 <- el_lm(clo ~ -1 + trt, clothianidin)
lhs2 <- list(
  "trtNaked - trtFungicide",
  "trtFungicide - trtLow",
  "trtLow - trtHigh"
)
elmt(fit2, lhs = lhs2)

## Arbitrary hypotheses (list `rhs` & list `lhs`)
data("mtcars")
fit3 <- el_lm(mpg ~ wt + qsec, data = mtcars)
lhs3 <- list(c(1, 4, 0), rbind(c(0, 1, 0), c(0, 0, 1)))
rhs3 <- list(0, c(-6, 1))
elmt(fit3, rhs = rhs3, lhs = lhs3)
```

ELMT-class

ELMT class

Description

S4 class for empirical likelihood multiple tests.

Slots

`coefficients` A list of numeric vectors of the estimates of the linear hypotheses.

`statistic` A numeric vector of minus twice the (constrained) empirical log-likelihood ratios with asymptotic chi-square distributions.

`df` An integer vector of the marginal degrees of freedom of the statistic.

`pval` A numeric vector for the multiplicity adjusted p -values.

`cv` A single numeric for the multiplicity adjusted critical value.

`rhs` A numeric vector for the right-hand sides of the hypotheses.

`lhs` A numeric matrix for the left-hand side of the hypotheses.

`alpha` A single numeric for the overall significance level.

`calibrate` A single character for the calibration method used.

Examples

```
showClass("ELMT")
```

elt	<i>Empirical likelihood test</i>
-----	----------------------------------

Description

Tests a linear hypothesis.

Usage

```
## S4 method for signature 'EL'
elt(
  object,
  rhs = NULL,
  lhs = NULL,
  alpha = 0.05,
  calibrate = "chisq",
  control = el_control()
)
```

Arguments

object	An object that inherits from EL .
rhs	A numeric vector or a column matrix for the right-hand side of hypothesis, with as many entries as the rows in 'lhs'. Defaults to 'NULL'. See 'Details'.
lhs	A numeric matrix or a vector (treated as a row matrix) for the left-hand side of a hypothesis. Each row gives a linear combination of the parameters in 'object'. The number of columns must be equal to the number of parameters. Or a character vector with a symbolic description of the hypothesis is allowed. Defaults to 'NULL'. See 'Details'.
alpha	A single numeric for the significance level. Defaults to '0.05'.
calibrate	A single character for the calibration method. It is case-insensitive and must be one of "chisq", "boot", or "f". Defaults to "chisq". See 'Details'.
control	An object of class ControlEL constructed by <code>[el_control()]</code> .

Details

`[elt()]` performs the constrained minimization of $l(\theta)$ described in [CEL](#). 'rhs' and 'lhs' cannot be both 'NULL'. For non-'NULL' 'lhs', it is required that 'lhs' have full row rank $q \leq p$ and p be equal to the number of parameters in the 'object'.

Depending on the specification of 'rhs' and 'lhs', we have the following three cases: 1. If both 'rhs' and 'lhs' are non-'NULL', the constrained minimization is performed with the right-hand side r and the left-hand side L as

$$\inf_{\theta: L\theta=r} l(\theta).$$

1. If 'rhs' is 'NULL', r is set to the zero vector as $\inf_{\theta: L\theta=0} l(\theta)$. 1. If 'lhs' is 'NULL', L is set to the identity matrix and the problem reduces to evaluating at r as $l(r)$.

'calibrate' specifies the calibration method used. Three methods are available: "chisq" (chi-square calibration), "boot" (bootstrap calibration), and "f" (F calibration). "boot" is applicable only when 'lhs' is 'NULL'. The 'nthreads', 'seed', and 'B' slots in 'control' apply to the bootstrap procedure. "f" is applicable only to the mean parameter when 'lhs' is 'NULL'.

Value

An object of class of [ELT](#). If 'lhs' is non-'NULL', the 'optim' slot corresponds to that of [CEL](#). Otherwise, it corresponds to that of [EL](#).

References

Adimari G, Guolo A (2010). "A Note on the Asymptotic Behaviour of Empirical Likelihood Statistics." *Statistical Methods & Applications*, 19(4), 463–476. doi:10.1007/s1026001001379.

Qin J, Lawless J (1995). "Estimating Equations, Empirical Likelihood and Constraints on Parameters." *Canadian Journal of Statistics*, 23(2), 145–159. doi:10.2307/3315441.

See Also

[ELT](#), [elmt\(\)](#), [el_control\(\)](#)

Examples

```
## F calibration for the mean
data("precip")
fit <- el_mean(precip, 32)
elt(fit, rhs = 32, calibrate = "f")

## Test of no treatment effect
data("clothianidin")
contrast <- matrix(c(
  1, -1, 0, 0,
  0, 1, -1, 0,
  0, 0, 1, -1
), byrow = TRUE, nrow = 3)
fit2 <- el_lm(clo ~ -1 + trt, clothianidin)
elt(fit2, lhs = contrast)

## A symbolic description of the same hypothesis
elt(fit2, lhs = c(
  "trtNaked - trtFungicide",
  "trtFungicide - trtLow",
  "trtLow - trtHigh"
))
```

 ELT-class

ELT class

Description

S4 class for empirical likelihood test.

Slots

`optim` A list of the following optimization results: * `'par'` A numeric vector of the solution to the (constrained) optimization problem. * `'lambda'` A numeric vector of the Lagrange multipliers of the dual problem corresponding to `'par'`. * `'iterations'` A single integer for the number of iterations performed. * `'convergence'` A single logical for the convergence status.

`logp` A numeric vector of the log probabilities of the (constrained) empirical likelihood.

`logl` A single numeric of the (constrained) empirical log-likelihood.

`loglr` A single numeric of the (constrained) empirical log-likelihood ratio.

`statistic` A single numeric of minus twice the (constrained) empirical log-likelihood ratio with an asymptotic chi-square distribution.

`df` A single integer for the chi-square degrees of freedom of the statistic.

`pval` A single numeric for the (calibrated) p -value of the statistic.

`cv` A single numeric for the critical value.

`rhs` A numeric vector for the right-hand side of the hypothesis.

`lhs` A numeric matrix for the left-hand side of the hypothesis.

`alpha` A single numeric for the significance level.

`calibrate` A single character for the calibration method used.

Examples

```
showClass("ELT")
```

 el_control

Control parameters for computation

Description

Specifies computational details of (constrained) empirical likelihood.

Usage

```

el_control(
  maxit = 200L,
  maxit_l = 25L,
  tol = 1e-06,
  tol_l = 1e-06,
  step = NULL,
  th = NULL,
  verbose = FALSE,
  keep_data = TRUE,
  nthreads,
  seed = sample.int(.Machine$integer.max, 1L),
  b = 10000L,
  m = 1000000L
)

```

Arguments

maxit	A single integer for the maximum number of iterations for constrained minimization of empirical likelihood. Defaults to '200'.
maxit_l	A single integer for the maximum number of iterations for evaluation of empirical likelihood. Defaults to '25'.
tol	A single numeric for the convergence tolerance for the constrained minimization. Defaults to '1e-06'.
tol_l	A single numeric for the relative convergence tolerance for the evaluation. Defaults to '1e-06'.
step	A single numeric for the step size for projected gradient descent method. Defaults to 'NULL' and set to the reciprocal of sample size.
th	A single numeric for the threshold for the negative empirical log-likelihood ratio. The iteration stops if the value exceeds the threshold. Defaults to 'NULL' and sets the threshold to '200 * d', where 'd' corresponds to the degrees of freedom of the limiting chi-squared distribution of the statistic.
verbose	A single logical. If 'TRUE', a message on the convergence status is printed when fitting objects that inherit from class EL . Defaults to 'FALSE'.
keep_data	A single logical. If 'TRUE', the data used for fitting objects that inherit from class EL are stored for later use with other methods. Defaults to 'TRUE'.
nthreads	A single integer for the number of threads for parallel computation via OpenMP (if available). Defaults to half the available threads. For better performance, it is generally recommended in most platforms to limit the number of threads to the number of physical cores. Note that it applies to the following functions that involve multiple evaluations or optimizations: <code>[confint()]</code> , <code>[confreg()]</code> , <code>[el_lm()]</code> , <code>[el_glm()]</code> , <code>[eld()]</code> , and <code>[elt()]</code> .
seed	A single integer for the seed for random number generation. It only applies to <code>[elt()]</code> when 'calibrate' is set to "boot". Defaults to a random integer generated from 1 to the maximum integer supported by R on the machine, which is

determined by [set.seed()]. Only one seed is needed even when multiple threads are used with 'nthreads'. Each thread is given a separate seed to produce a non-overlapping but reproducible sequence of random numbers. The Xoshiro256+ pseudo-random number generator is used internally to work with OpenMP.

- b A single integer for the number of bootstrap replicates. It only applies to [elt()] when 'calibrate' is set to "boot". Defaults to '10000'.
- m A single integer for the number of Monte Carlo samples. It only applies to [elmt()]. Defaults to '1e+06'.

Value

An object of class of [ControlEL](#).

See Also

[el_eval()], [elt()]

Examples

```
optcfg <- el_control(maxit = 300, step = 0.01, th = 200, nthreads = 1)
```

el_eval

Empirical likelihood for general estimating functions

Description

Computes empirical likelihood with general estimating functions.

Usage

```
el_eval(g, weights = NULL, control = el_control())
```

Arguments

- g A numeric matrix, or an object that can be coerced to a numeric matrix. Each row corresponds to an observation of an estimating function. The number of rows must be greater than the number of columns.
- weights An optional numeric vector of weights to be used in the fitting process. The length of the vector must be the same as the number of rows in 'g'. Defaults to 'NULL', corresponding to identical weights. If non-'NULL', weighted empirical likelihood is computed.
- control An object of class [ControlEL](#) constructed by [el_control()].

Details

Let X_i be independent and identically distributed p -dimensional random variable from an unknown distribution P for $i = 1, \dots, n$. We assume that P has a positive definite covariance matrix. For a parameter of interest $\theta(F) \in \mathbb{R}^p$, consider a p -dimensional smooth estimating function $g(X_i, \theta)$ with a moment condition

$$E[g(X_i, \theta)] = 0.$$

We assume that there exists a unique θ_0 that solves the above equation. Given a value of θ , the (profile) empirical likelihood ratio is defined by

$$R(\theta) = \max_{p_i} \left\{ \prod_{i=1}^n np_i : \sum_{i=1}^n p_i g(X_i, \theta) = 0, p_i \geq 0, \sum_{i=1}^n p_i = 1 \right\}.$$

[el_mean()] computes the empirical log-likelihood ratio statistic $-2 \log R(\theta)$ with the n by p numeric matrix 'g', whose i th row is $g(X_i, \theta)$. Since the estimating function can be arbitrary, [el_eval()] does not return an object of class **EL**, and the associated generics and methods are not applicable.

Value

A list of the following optimization results: * 'optim' A list with the following optimization results: * 'lambda' A numeric vector of the Lagrange multipliers of the dual problem. * 'iterations' A single integer for the number of iterations performed. * 'convergence' A single logical for the convergence status. * 'logp' A numeric vector of the log probabilities of the empirical likelihood. * 'logl' A single numeric of the empirical log-likelihood. * 'loglr' A single numeric of the empirical log-likelihood ratio. * 'statistic' A single numeric of minus twice the empirical log-likelihood ratio with an asymptotic chi-square distribution. * 'df' A single integer for the degrees of freedom of the statistic. * 'pval' A single numeric for the p -value of the statistic. * 'nobs' A single integer for the number of observations. * 'npar' A single integer for the number of parameters. * 'weights' A numeric vector of the re-scaled weights used for the model fitting.

References

Qin J, Lawless J (1994). "Empirical Likelihood and General Estimating Equations." *The Annals of Statistics*, 22(1), 300–325. doi:10.1214/aos/1176325370.

See Also

EL, [el_control()]

Examples

```
set.seed(123526)
mu <- 0
sigma <- 1
x <- rnorm(100)
g <- matrix(c(x - mu, (x - mu)^2 - sigma^2), ncol = 2)
el_eval(g, weights = rep(c(1, 2), each = 50))
```

Description

Fits a generalized linear model with empirical likelihood.

Usage

```
el_glm(
  formula,
  family = gaussian,
  data,
  weights = NULL,
  na.action,
  start = NULL,
  etastart = NULL,
  mustart = NULL,
  offset,
  control = el_control(),
  ...
)
```

Arguments

formula	An object of class [<code>'formula'</code>] (or one that can be coerced to that class): a symbolic description of the model to be fitted.
family	A description of the error distribution and link function to be used in the model. Only the result of a call to a family function is supported. See <code>'Details'</code> .
data	An optional data frame, list or environment (or object coercible by <code>[as.data.frame()]</code> to a data frame) containing the variables in the formula. If not found in data, the variables are taken from <code>'environment(formula)'</code> .
weights	An optional numeric vector of weights to be used in the fitting process. Defaults to <code>'NULL'</code> , corresponding to identical weights. If non- <code>'NULL'</code> , weighted empirical likelihood is computed.
na.action	A function which indicates what should happen when the data contain <code>'NA'</code> 's. The default is set by the <code>'na.action'</code> setting of [<code>'options'</code>], and is <code>'na.fail'</code> if that is unset.
start	Starting values for the parameters in the linear predictor. Defaults to <code>'NULL'</code> and is passed to <code>[glm.fit()]</code> .
etastart	Starting values for the linear predictor. Defaults to <code>'NULL'</code> and is passed to <code>[glm.fit()]</code> .
mustart	Starting values for the vector of means. Defaults to <code>'NULL'</code> and is passed to <code>[glm.fit()]</code> .

offset	An optional expression for specifying an <i>a priori</i> known component to be included in the linear predictor during fitting. This should be 'NULL' or a numeric vector or matrix of extents matching those of the response. One or more ['offset'] terms can be included in the formula instead or as well, and if more than one are specified their sum is used.
control	An object of class <code>ControlEL</code> constructed by <code>[el_control()]</code> .
...	Additional arguments to be passed to <code>[glm.control()]</code> .

Details

Suppose that we observe n independent random variables $Z_i \equiv (X_i, Y_i)$ from a common distribution, where X_i is the p -dimensional covariate (including the intercept if any) and Y_i is the response. A generalized linear model specifies that $E(Y_i|X_i) = \mu_i$, $G(\mu_i) = X_i^\top \theta$, and $\text{Var}(Y_i|X_i) = \phi V(\mu_i)$, where $\theta = (\theta_0, \dots, \theta_{p-1})$ is an unknown p -dimensional parameter, ϕ is an optional dispersion parameter, G is a known smooth link function, and V is a known variance function.

With H denoting the inverse link function, define the quasi-score

$$g_1(Z_i, \theta) = \{H'(X_i^\top \theta) (Y_i - H(X_i^\top \theta)) / (\phi V(H(X_i^\top \theta)))\} X_i.$$

Then we have the estimating equations $\sum_{i=1}^n g_1(Z_i, \theta) = 0$. When ϕ is known, the (profile) empirical likelihood ratio for a given θ is defined by

$$R_1(\theta) = \max_{p_i} \left\{ \prod_{i=1}^n p_i : \sum_{i=1}^n p_i g_1(Z_i, \theta) = 0, p_i \geq 0, \sum_{i=1}^n p_i = 1 \right\}.$$

With unknown ϕ , we introduce another estimating function based on the squared residuals. Let $\eta = (\theta, \phi)$ and

$$g_2(Z_i, \eta) = (Y_i - H(X_i^\top \theta))^2 / (\phi^2 V(H(X_i^\top \theta))) - 1/\phi.$$

Now the empirical likelihood ratio is defined by

$$R_2(\eta) = \max_{p_i} \left\{ \prod_{i=1}^n p_i : \sum_{i=1}^n p_i g_1(Z_i, \eta) = 0, \sum_{i=1}^n p_i g_2(Z_i, \eta) = 0, p_i \geq 0, \sum_{i=1}^n p_i = 1 \right\}.$$

`[el_glm()]` first computes the parameter estimates by calling `[glm.fit()]` (with '...' if any) with the 'model.frame' and 'model.matrix' obtained from the 'formula'. Note that the maximum empirical likelihood estimator is the same as the quasi-maximum likelihood estimator in our model. Next, it tests hypotheses based on asymptotic chi-square distributions of the empirical likelihood ratio statistics. Included in the tests are overall test with

$$H_0 : \theta_1 = \theta_2 = \dots = \theta_{p-1} = 0,$$

and significance tests for each parameter with

$$H_{0j} : \theta_j = 0, j = 0, \dots, p-1.$$

The available families and link functions are as follows: * 'gaussian': "identity", "log", and "inverse". * 'binomial': "logit", "probit", and "log". * 'poisson': "log", "identity", and "sqrt". * 'quasipoisson': "log" and "identity".

Value

An object of class of [GLM](#).

References

Chen SX, Cui H (2003). “An Extended Empirical Likelihood for Generalized Linear Models.” *Statistica Sinica*, 13(1), 69–81.

Kolaczyk ED (1994). “Empirical Likelihood for Generalized Linear Models.” *Statistica Sinica*, 4(1), 199–218.

See Also

[EL](#), [GLM](#), `[el_lm()]`, `[elt()]`, `[el_control()]`

Examples

```
data("warpbreaks")
fit <- el_glm(wool ~ .,
  family = binomial, data = warpbreaks, weights = NULL, na.action = na.omit,
  start = NULL, etastart = NULL, mustart = NULL, offset = NULL
)
summary(fit)
```

el_lm

Empirical likelihood for linear models

Description

Fits a linear model with empirical likelihood.

Usage

```
el_lm(
  formula,
  data,
  weights = NULL,
  na.action,
  offset,
  control = el_control(),
  ...
)
```

Arguments

formula	An object of class [<code>'formula'</code>] (or one that can be coerced to that class) for a symbolic description of the model to be fitted.
data	An optional data frame, list or environment (or object coercible by <code>[as.data.frame()]</code> to a data frame) containing the variables in <code>'formula'</code> . If not found in data, the variables are taken from <code>'environment(formula)'</code> .
weights	An optional numeric vector of weights to be used in the fitting process. Defaults to <code>'NULL'</code> , corresponding to identical weights. If non- <code>'NULL'</code> , weighted empirical likelihood is computed.
na.action	A function which indicates what should happen when the data contain <code>'NA'</code> 's. The default is set by the <code>'na.action'</code> setting of [<code>'options'</code>], and is <code>'na.fail'</code> if that is unset.
offset	An optional expression for specifying an <i>a priori</i> known component to be included in the linear predictor during fitting. This should be <code>'NULL'</code> or a numeric vector or matrix of extents matching those of the response. One or more [<code>'offset'</code>] terms can be included in the formula instead or as well, and if more than one are specified their sum is used.
control	An object of class <code>ControlEL</code> constructed by <code>[el_control()]</code> .
...	Additional arguments to be passed to the low level regression fitting functions. See <code>'Details'</code> .

Details

Suppose that we observe n independent random variables $Z_i \equiv (X_i, Y_i)$ from a common distribution, where X_i is the p -dimensional covariate (including the intercept if any) and Y_i is the response. We consider the following linear model:

$$Y_i = X_i^\top \theta + \epsilon_i,$$

where $\theta = (\theta_0, \dots, \theta_{p-1})$ is an unknown p -dimensional parameter and the errors ϵ_i are independent random variables that satisfy $E(\epsilon_i | X_i) = 0$. We assume that the errors have finite conditional variance. Then the least square estimator of θ solves the following estimating equations:

$$\sum_{i=1}^n (Y_i - X_i^\top \theta) X_i = 0.$$

Given a value of θ , let $g(Z_i, \theta) = (Y_i - X_i^\top \theta) X_i$ and the (profile) empirical likelihood ratio is defined by

$$R(\theta) = \max_{p_i} \left\{ \prod_{i=1}^n n p_i : \sum_{i=1}^n p_i g(Z_i, \theta) = \theta, p_i \geq 0, \sum_{i=1}^n p_i = 1 \right\}.$$

`[el_lm()]` first computes the parameter estimates by calling `[lm.fit()]` (with `'...'` if any) with the `'model.frame'` and `'model.matrix'` obtained from the `'formula'`. Note that the maximum empirical likelihood estimator is the same as the the quasi-maximum likelihood estimator in our model. Next, it tests hypotheses based on asymptotic chi-square distributions of the empirical likelihood ratio statistics. Included in the tests are overall test with

$$H_0 : \theta_1 = \theta_2 = \dots = \theta_{p-1} = 0,$$

and significance tests for each parameter with

$$H_{0j} : \theta_j = 0, j = 0, \dots, p - 1.$$

Value

An object of class of [LM](#).

References

Owen A (1991). "Empirical Likelihood for Linear Models." *The Annals of Statistics*, 19(4), 1725–1747. doi:[10.1214/aos/1176348368](https://doi.org/10.1214/aos/1176348368).

See Also

[EL](#), [LM](#), [\[el_glm\(\)\]](#), [\[elt\(\)\]](#), [\[el_control\(\)\]](#)

Examples

```
## Linear model
data("thiamethoxam")
fit <- el_lm(fruit ~ trt, data = thiamethoxam)
summary(fit)

## Weighted data
wfit <- el_lm(fruit ~ trt, data = thiamethoxam, weights = visit)
summary(wfit)

## Missing data
fit2 <- el_lm(fruit ~ trt + scb, data = thiamethoxam,
  na.action = na.omit, offset = NULL
)
summary(fit2)
```

el_mean

Empirical likelihood for the mean

Description

Computes empirical likelihood for the mean.

Usage

```
el_mean(x, par, weights = NULL, control = el_control())
```

Arguments

x	A numeric matrix, or an object that can be coerced to a numeric matrix. Each row corresponds to an observation. The number of rows must be greater than the number of columns.
par	A numeric vector of parameter values to be tested. The length of the vector must be the same as the number of columns in 'x'.
weights	An optional numeric vector of weights to be used in the fitting process. The length of the vector must be the same as the number of rows in 'x'. Defaults to 'NULL', corresponding to identical weights. If non-'NULL', weighted empirical likelihood is computed.
control	An object of class <code>ControlEL</code> constructed by <code>[el_control()]</code> .

Details

Let X_i be independent and identically distributed p -dimensional random variable from an unknown distribution P for $i = 1, \dots, n$. We assume that $E[X_i] = \theta_0 \in \mathbb{R}^p$ and that P has a positive definite covariance matrix. Given a value of θ , the (profile) empirical likelihood ratio is defined by

$$R(\theta) = \max_{p_i} \left\{ \prod_{i=1}^n np_i : \sum_{i=1}^n p_i X_i = \theta, p_i \geq 0, \sum_{i=1}^n p_i = 1 \right\}.$$

`[el_mean()]` computes the empirical log-likelihood ratio statistic $-2 \log R(\theta)$, along with other values in `EL`.

Value

An object of class `EL`.

References

Owen A (1990). "Empirical Likelihood Ratio Confidence Regions." *The Annals of Statistics*, 18(1), 90–120. doi:10.1214/aos/1176347494.

See Also

`EL`, `[elt()]`, `[el_eval()]`, `[el_control()]`

Examples

```
## Scalar mean
data("precip")
el_mean(precip, 30)

## Vector mean
data("faithful")
el_mean(faithful, par = c(3.5, 70))

## Weighted data
w <- rep(c(1, 2), each = nrow(faithful) / 2)
el_mean(faithful, par = c(3.5, 70), weights = w)
```

el_sd

*Empirical likelihood for the standard deviation***Description**

Computes empirical likelihood for the standard deviation.

Usage

```
el_sd(x, mean, sd, weights = NULL, control = el_control())
```

Arguments

x	A numeric vector, or an object that can be coerced to a numeric vector.
mean	A single numeric for the (known) mean value.
sd	A positive single numeric for the parameter value to be tested.
weights	An optional numeric vector of weights to be used in the fitting process. The length of the vector must be the same as the length of 'x'. Defaults to 'NULL', corresponding to identical weights. If non-'NULL', weighted empirical likelihood is computed.
control	An object of class ControlEL constructed by <code>[el_control()]</code> .

Details

Let X_i be independent and identically random variable from an unknown distribution P for $i = 1, \dots, n$. We assume that $E[X_i] = \mu_0$ is known and that P has a variance σ_0^2 . Given a value of σ , the (profile) empirical likelihood ratio is defined by

$$R(\sigma) = \max_{p_i} \left\{ \prod_{i=1}^n np_i : \sum_{i=1}^n p_i (X_i - \mu_0)^2 = \sigma^2, p_i \geq 0, \sum_{i=1}^n p_i = 1 \right\}.$$

`[el_sd()]` computes the empirical log-likelihood ratio statistic $-2 \log R(\sigma)$, along with other values in [SD](#).

Value

An object of class [SD](#).

See Also

[EL](#), [SD](#), `[el_mean()]`, `[elt()]`, `[el_control()]`

Examples

```
data("women")
x <- women$height
w <- women$weight
el_sd(x, mean = 65, sd = 5, weights = w)
```

`getDF`*Degrees of freedom*

Description

Extracts degrees of freedom from a model.

Usage

```
## S4 method for signature 'EL'  
getDF(object)  
  
## S4 method for signature 'ELMT'  
getDF(object)  
  
## S4 method for signature 'ELT'  
getDF(object)  
  
## S4 method for signature 'logLikEL'  
getDF(object)  
  
## S4 method for signature 'SummaryLM'  
getDF(object)
```

Arguments

`object` An object that inherits from [EL](#), [ELT](#), [ELMT](#), or [SummaryLM](#).

Value

An integer vector.

Methods (by class)

- `getDF(EL)`: Extracts the degrees of freedom.
- `getDF(ELMT)`: Extracts the vector of marginal degrees of freedom.
- `getDF(ELT)`: Extracts the (chi-square) degrees of freedom.
- `getDF(logLikEL)`: Extracts the degrees of freedom.
- `getDF(SummaryLM)`: Extracts the degrees of freedom.

See Also

[EL](#), [ELT](#), [ELMT](#), [SummaryLM](#)

Examples

```
data("faithful")
fit <- el_mean(faithful, par = c(3.5, 70))
getDF(fit)
```

`getOptim`*Optimization results*

Description

Extracts optimization results from a model.

Usage

```
## S4 method for signature 'EL'
getOptim(object, ...)

## S4 method for signature 'ELT'
getOptim(object, ...)
```

Arguments

<code>object</code>	An object that inherits from EL or ELT .
<code>...</code>	Further arguments passed to methods.

Value

A list with the following optimization results: * `'par'` A numeric vector of the parameter value. See the documentation of [EL](#) and [CEL](#). * `'lambda'` A numeric vector of the Lagrange multipliers. * `'iterations'` A single integer for the number of iterations performed. * `'convergence'` A single logical for the convergence status.

See Also

[EL](#), [CEL](#), [ELT](#), [[sigTests\(\)](#)]

Examples

```
data("precip")
fit <- el_mean(precip, par = 40)
getOptim(fit)
```

GLM-class

*GLM class***Description**

S4 class for generalized linear models. It inherits from [LM](#) class.

Details

The overall test involves a constrained optimization problem. All the parameters except for the intercept are constrained to zero. The 'optim' slot contains the results. When there is no intercept, all parameters are set to zero, and the results need to be understood in terms of [EL](#) class since no constrained optimization is involved. Once the solution is found, the log probabilities ('logp') and the (constrained) empirical likelihood values ('logl', 'loglr', 'statistic') readily follow, along with the degrees of freedom ('df') and the *p*-value ('pval'). The significance tests for each parameter also involve constrained optimization problems where only one parameter is constrained to zero. The 'sigTests' slot contains the results.

Slots

family A ['family'] object used.

dispersion A single numeric for the estimated dispersion parameter.

sigTests A list of the following results of significance tests: * 'statistic' A numeric vector of minus twice the (constrained) empirical log-likelihood ratios with asymptotic chi-square distributions. * 'iterations' An integer vector for the number of iterations performed for each parameter. * 'convergence' A logical vector for the convergence status of each parameter.

call A matched call.

terms A ['terms'] object used.

misc A list of various outputs obtained from the model fitting process. They are used in other generics and methods.

optim A list of the following optimization results: * 'par' A numeric vector of the solution to the (constrained) optimization problem. * 'lambda' A numeric vector of the Lagrange multipliers of the dual problem corresponding to 'par'. * 'iterations' A single integer for the number of iterations performed. * 'convergence' A single logical for the convergence status.

logp A numeric vector of the log probabilities of the (constrained) empirical likelihood.

logl A single numeric of the (constrained) empirical log-likelihood.

loglr A single numeric of the (constrained) empirical log-likelihood ratio.

statistic A single numeric of minus twice the (constrained) empirical log-likelihood ratio with an asymptotic chi-square distribution.

df A single integer for the degrees of freedom of the statistic.

pval A single numeric for the *p*-value of the statistic.

nobs A single integer for the number of observations.

npar A single integer for the number of parameters.

weights A numeric vector of the re-scaled weights used for the model fitting.
 coefficients A numeric vector of the maximum empirical likelihood estimates of the parameters.
 method A single character for the method dispatch in internal functions.
 data A numeric matrix of the data for the model fitting.

Examples

```
showClass("GLM")
```

LM-class	<i>LM class</i>
----------	-----------------

Description

S4 class for linear models with empirical likelihood. It inherits from [CEL](#) class.

Details

The overall test involves a constrained optimization problem. All the parameters except for the intercept are constrained to zero. The 'optim' slot contains the results. When there is no intercept, all parameters are set to zero, and the results need to be understood in terms of [EL](#) class since no constrained optimization is involved. Once the solution is found, the log probabilities ('logp') and the (constrained) empirical likelihood values ('logl', 'loglr', 'statistic') readily follow, along with the degrees of freedom ('df') and the *p*-value ('pval'). The significance tests for each parameter also involve constrained optimization problems where only one parameter is constrained to zero. The 'sigTests' slot contains the results.

Methods (by generic)

- formula(LM): Extracts the symbolic model formula used in [`el_lm()`] or [`el_glm()`].

Slots

sigTests A list of the following results of significance tests: * 'statistic' A numeric vector of minus twice the (constrained) empirical log-likelihood ratios with asymptotic chi-square distributions. * 'iterations' An integer vector for the number of iterations performed for each parameter. * 'convergence' A logical vector for the convergence status of each parameter.

call A matched call.

terms A [`'terms'`] object used.

misc A list of various outputs obtained from the model fitting process. They are used in other generics and methods.

optim A list of the following optimization results: * 'par' A numeric vector of the solution to the (constrained) optimization problem. * 'lambda' A numeric vector of the Lagrange multipliers of the dual problem corresponding to 'par'. * 'iterations' A single integer for the number of iterations performed. * 'convergence' A single logical for the convergence status.

`logp` A numeric vector of the log probabilities of the (constrained) empirical likelihood.
`logl` A single numeric of the (constrained) empirical log-likelihood.
`loglr` A single numeric of the (constrained) empirical log-likelihood ratio.
`statistic` A single numeric of minus twice the (constrained) empirical log-likelihood ratio with an asymptotic chi-square distribution.
`df` A single integer for the degrees of freedom of the statistic.
`pval` A single numeric for the p -value of the statistic.
`nobs` A single integer for the number of observations.
`npar` A single integer for the number of parameters.
`weights` A numeric vector of the re-scaled weights used for the model fitting.
`coefficients` A numeric vector of the maximum empirical likelihood estimates of the parameters.
`method` A single character for the method dispatch in internal functions.
`data` A numeric matrix of the data for the model fitting.

Examples

```
showClass("LM")
```

logL	<i>Empirical log-likelihood</i>
------	---------------------------------

Description

Extracts empirical log-likelihood from a model.

Usage

```
## S4 method for signature 'EL'
logL(object, ...)

## S4 method for signature 'ELT'
logL(object, ...)
```

Arguments

<code>object</code>	An object that inherits from EL or ELT .
<code>...</code>	Further arguments passed to methods.

Value

A single numeric.

References

Baggerly KA (1998). "Empirical Likelihood as a Goodness-of-Fit Measure." *Biometrika*, 85(3), 535–547. doi:10.1093/biomet/asm094.

See Also

[EL](#), [ELT](#)

Examples

```
data("precip")
fit <- el_mean(precip, par = 40)
logL(fit)
```

logLik

Maximum empirical log-likelihood

Description

Extracts empirical log-likelihood from a model evaluated at the estimated coefficients.

Usage

```
## S4 method for signature 'EL'
logLik(object, ...)
```

Arguments

`object` An object that inherits from [EL](#).
`...` Further arguments passed to methods.

Details

Let X_i be independent and identically distributed p -dimensional random variable from an unknown distribution P for $i = 1, \dots, n$. We assume that P has a positive definite covariance matrix. For a parameter of interest $\theta(F) \in \mathbb{R}^p$, consider a p -dimensional smooth estimating function $g(X_i, \theta)$ with a moment condition

$$E[g(X_i, \theta)] = 0.$$

We assume that there exists a unique θ_0 that solves the above equation. Given a value of θ , the (profile) empirical likelihood ratio is defined by

$$R(\theta) = \max_{p_i} \left\{ \prod_{i=1}^n np_i : \sum_{i=1}^n p_i g(X_i, \theta) = 0, p_i \geq 0, \sum_{i=1}^n p_i = 1 \right\}.$$

The maximum empirical likelihood estimator $\hat{\theta}$ solves $n^{-1} \sum_{i=1}^n g(X_i, \hat{\theta}) = 0$ and yields $p_i = 1/n$ for $i = 1, \dots, n$. `[logLik()]` gives $-n \log R(\hat{\theta})$, the maximum empirical log-likelihood. Use `[logL()]` instead to extract the (constrained) empirical log-likelihood computed from a model.

Value

An object of class `logLikEL`.

See Also

`EL`, `[logL()]`

Examples

```
data("precip")
fit <- el_mean(precip, par = 40)
logLik(fit)
```

<code>logLikEL-class</code>	<i>logLikEL class</i>
-----------------------------	-----------------------

Description

S4 class for empirical log-likelihood. It inherits from "numeric".

Slots

`df` A single integer for the degrees of freedom or the number of (estimated) parameters in the model.

Examples

```
showClass("logLikEL")
```

<code>logLR</code>	<i>Empirical log-likelihood ratio</i>
--------------------	---------------------------------------

Description

Extracts empirical log-likelihood ratio from a model.

Usage

```
## S4 method for signature 'EL'
logLR(object, ...)

## S4 method for signature 'ELT'
logLR(object, ...)
```

Arguments

object An object that inherits from [EL](#) or [ELT](#).
 ... Further arguments passed to methods.

Value

A single numeric.

References

Baggerly KA (1998). “Empirical Likelihood as a Goodness-of-Fit Measure.” *Biometrika*, 85(3), 535–547. doi:[10.1093/biomet/asm094](https://doi.org/10.1093/biomet/asm094).

See Also

[EL](#), [ELT](#)

Examples

```
data("precip")
fit <- el_mean(precip, par = 40)
logLR(fit)
```

logProb	<i>Log probabilities</i>
---------	--------------------------

Description

Extracts log probabilities of empirical likelihood from a model.

Usage

```
## S4 method for signature 'EL'
logProb(object, ...)

## S4 method for signature 'ELT'
logProb(object, ...)
```

Arguments

object An object that inherits from [EL](#) or [ELT](#).
 ... Further arguments passed to methods.

Value

A numeric vector.

See Also

[EL](#), [ELT](#)

Examples

```
data("precip")
fit <- el_mean(precip, par = 40)
logProb(fit)
```

nobs	<i>Number of observations in a model</i>
------	--

Description

Extracts number of observations from a model.

Usage

```
## S4 method for signature 'EL'
nobs(object, ...)
```

Arguments

object	An object that inherits from EL .
...	Further arguments passed to methods.

Value

A single integer.

See Also

[EL](#)

Examples

```
data("precip")
fit <- el_mean(precip, par = 40)
nobs(fit)
```

plot

Plot methods

Description

Provides plot methods for objects.

Usage

```
## S4 method for signature 'ConfregEL'
plot(x, y, ...)

## S4 method for signature 'EL'
plot(x, y, ...)

## S4 method for signature 'ELD'
plot(x, y, ...)
```

Arguments

x	An object that inherits from EL , ELD , or ConfregEL .
y	Not used.
...	Further graphical parameters (see [<code>'par'</code>]).

Value

No return value, called for side effects.

Methods (by class)

- `plot(ConfregEL)`: Plots a two-dimensional confidence region for model parameters.
- `plot(EL)`: Plots empirical likelihood displacement values versus observation index. `'eld()'` is called implicitly.
- `plot(ELD)`: Plots empirical likelihood displacement values versus observation index.

See Also

[EL](#), [ConfregEL](#), [ELD](#), [`confreg()`], [`eld()`]

Examples

```
## Model
data("mtcars")
fit <- el_lm(hp ~ wt, data = mtcars)

## Confidence region
out1 <- confreg(fit, npoints = 500)
```

```

plot(out1)

## Empirical likelihood displacement
out2 <- eld(fit)
plot(out2)

## A shortcut to `ELD`
plot(fit)

```

print

Print methods

Description

Provides print methods for objects.

Usage

```

## S4 method for signature 'EL'
print(x, digits = max(3L, getOption("digits") - 3L), ...)

## S4 method for signature 'ELMT'
print(
  x,
  digits = max(3L, getOption("digits") - 3L),
  signif.stars = getOption("show.signif.stars"),
  ...
)

## S4 method for signature 'ELT'
print(x, digits = max(3L, getOption("digits") - 3L), ...)

## S4 method for signature 'LM'
print(x, digits = max(3L, getOption("digits") - 3L), ...)

## S4 method for signature 'logLikEL'
print(x, digits = getOption("digits"), ...)

## S4 method for signature 'SummaryGLM'
print(
  x,
  digits = max(3L, getOption("digits") - 3L),
  signif.stars = getOption("show.signif.stars"),
  ...
)

## S4 method for signature 'SummaryLM'
print(

```



```

    x,
    digits = max(3L, getOption("digits") - 3L),
    signif.stars = getOption("show.signif.stars"),
    ...
  )

## S4 method for signature 'SummaryQGLM'
print(
  x,
  digits = max(3L, getOption("digits") - 3L),
  signif.stars = getOption("show.signif.stars"),
  ...
)

```

Arguments

`x` An object that inherits from [EL](#), [ELT](#), [ELMT](#), or [SummaryLM](#).

`...` Further arguments passed to methods.

`digits` A single integer for the number of significant digits to be passed to `[format()]`.

`signif.stars` A single logical. If 'TRUE', 'significance stars' are printed for each parameter.

Value

The argument 'x' (invisibly).

See Also

[EL](#), [ELT](#), [ELMT](#), [LM](#), [SummaryLM](#), [SummaryGLM](#), [SummaryQGLM](#)

Examples

```

data("precip")
fit <- el_mean(precip, par = 40)
print(fit)

```

pVal

p-value

Description

Extracts *p*-value from a model.

Usage

```
## S4 method for signature 'EL'  
pVal(object, ...)  
  
## S4 method for signature 'ELMT'  
pVal(object, ...)  
  
## S4 method for signature 'ELT'  
pVal(object, ...)
```

Arguments

object	An object that inherits from EL , ELT , or ELMT .
...	Further arguments passed to methods.

Value

The form of the value returned by [pVal()] depends on the class of its argument.

Methods (by class)

- pVal(EL): Extracts the p -value.
- pVal(ELMT): Extracts the multiplicity adjusted p -values.
- pVal(ELT): Extracts the p -value.

See Also

[EL](#), [ELT](#), [ELMT](#), [chisq()]

Examples

```
data("precip")  
fit <- el_mean(precip, par = 40)  
pVal(fit)
```

QGLM-class

QGLM class

Description

S4 class for generalized linear models with quasi-likelihood methods. It inherits from [GLM](#) class.

Details

The overall test involves a constrained optimization problem. All the parameters except for the intercept are constrained to zero. The 'optim' slot contains the results. When there is no intercept, all parameters are set to zero, and the results need to be understood in terms of [EL](#) class since no constrained optimization is involved. Once the solution is found, the log probabilities ('logp') and the (constrained) empirical likelihood values ('logl', 'loglr', 'statistic') readily follow, along with the degrees of freedom ('df') and the *p*-value ('pval'). The significance tests for each parameter also involve constrained optimization problems where only one parameter is constrained to zero. The 'sigTests' slot contains the results.

Slots

family A ['family'] object used.

dispersion A single numeric for the estimated dispersion parameter.

sigTests A list of the following results of significance tests: * 'statistic' A numeric vector of minus twice the (constrained) empirical log-likelihood ratios with asymptotic chi-square distributions. * 'iterations' An integer vector for the number of iterations performed for each parameter. * 'convergence' A logical vector for the convergence status of each parameter.

call A matched call.

terms A ['terms'] object used.

misc A list of various outputs obtained from the model fitting process. They are used in other generics and methods.

optim A list of the following optimization results: * 'par' A numeric vector of the solution to the (constrained) optimization problem. * 'lambda' A numeric vector of the Lagrange multipliers of the dual problem corresponding to 'par'. * 'iterations' A single integer for the number of iterations performed. * 'convergence' A single logical for the convergence status.

logp A numeric vector of the log probabilities of the (constrained) empirical likelihood.

logl A single numeric of the (constrained) empirical log-likelihood.

loglr A single numeric of the (constrained) empirical log-likelihood ratio.

statistic A single numeric of minus twice the (constrained) empirical log-likelihood ratio with an asymptotic chi-square distribution.

df A single integer for the degrees of freedom of the statistic.

pval A single numeric for the *p*-value of the statistic.

nobs A single integer for the number of observations.

npar A single integer for the number of parameters.

weights A numeric vector of the re-scaled weights used for the model fitting.

coefficients A numeric vector of the maximum empirical likelihood estimates of the parameters.

method A single character for the method dispatch in internal functions.

data A numeric matrix of the data for the model fitting.

Examples

```
showClass("QGLM")
```

SD-class

SD class

Description

S4 class for standard deviation. It inherits from [EL](#) class.

Slots

`optim` A list of the following optimization results: * `'par'` A numeric vector of the solution to the optimization problem. * `'lambda'` A numeric vector of the Lagrange multipliers of the dual problem corresponding to `'par'`. * `'iterations'` A single integer for the number of iterations performed. * `'convergence'` A single logical for the convergence status.

`logp` A numeric vector of the log probabilities of the empirical likelihood.

`logl` A single numeric of the empirical log-likelihood.

`loglr` A single numeric of the empirical log-likelihood ratio.

`statistic` A single numeric of minus twice the empirical log-likelihood ratio with an asymptotic chi-square distribution.

`df` A single integer for the degrees of freedom of the statistic.

`pval` A single numeric for the p -value of the statistic.

`nobs` A single integer for the number of observations.

`npar` A single integer for the number of parameters.

`weights` A numeric vector of the re-scaled weights used for the model fitting.

`coefficients` A numeric vector of the maximum empirical likelihood estimates of the parameters.

`method` A single character for the method dispatch in internal functions.

`data` A numeric matrix of the data for the model fitting.

Examples

```
showClass("SD")
```

sigTests

Significance tests

Description

Extracts the results of significance tests from a model.

Usage

```
## S4 method for signature 'LM'
sigTests(object, ...)

## S4 method for signature 'SummaryLM'
sigTests(object, ...)
```

Arguments

object An object that inherits from [LM](#) or [SummaryLM](#).
 ... Further arguments passed to methods.

Value

The form of the value returned by [sigTests()] depends on the class of its argument.

Methods (by class)

- sigTests(LM): Extracts a list with the optimization results of significance tests.
- sigTests(SummaryLM): Extracts a matrix with the results of significance tests.

See Also

[LM](#), [SummaryLM](#), [getOptim()]

Examples

```
data("mtcars")
fit <- el_lm(mpg ~ ., data = mtcars)
sigTests(fit)
sigTests(summary(fit))
```

summary

Summary methods

Description

Provides summary methods for objects.

Usage

```
## S4 method for signature 'LM'
summary(object, ...)

## S4 method for signature 'GLM'
summary(object, ...)

## S4 method for signature 'QGLM'
summary(object, ...)
```

Arguments

object An object that inherits from [LM](#).
 ... Further arguments passed to methods.

Value

The form of the value returned by [summary()] depends on the class of its argument.

Methods (by class)

- `summary(LM)`: Summarizes the results of the overall model test and the significance tests for coefficients.
- `summary(GLM)`: Summarizes the results of the overall model test and the significance tests for coefficients. The dispersion parameter is extracted for display.
- `summary(QGLM)`: Summarizes the results of the overall model test and the significance tests for coefficients. The estimated dispersion parameter is extracted for display.

See Also

[LM](#), [GLM](#), [QGLM](#)

Examples

```
data("mtcars")
fit <- el_lm(mpg ~ wt, data = mtcars)
summary(fit)
```

SummaryGLM-class

SummaryGLM class

Description

S4 class for a summary of [GLM](#) objects. It inherits from [SummaryLM](#) class.

Slots

`family` A ['family'] object used.
`dispersion` A single numeric for the estimated dispersion parameter.
`statistic` A single numeric of minus twice the (constrained) empirical log-likelihood ratio for the overall test.
`df` A single integer for the degrees of freedom of the statistic.
`convergence` A single logical for the convergence status of the constrained minimization.
`sigTests` A numeric matrix of the results of significance tests.
`weighted` A single logical for whether the given model is weighted or not.

intercept A single logical for whether the given model has an intercept term or not.
 na.action Information returned by [`'model.frame'`] on the special handling of `'NA'`s.
 call A matched call.
 terms A [`'terms'`] object used.
 aliased A named logical vector showing if the original coefficients are aliased.

Examples

```
showClass("SummaryGLM")
```

SummaryLM-class	<i>SummaryLM class</i>
-----------------	------------------------

Description

S4 class for a summary of [LM](#) objects.

Slots

statistic A single numeric of minus twice the (constrained) empirical log-likelihood ratio for the overall test.
 df A single integer for the degrees of freedom of the statistic.
 convergence A single logical for the convergence status of the constrained minimization.
 sigTests A numeric matrix of the results of significance tests.
 weighted A single logical for whether the given model is weighted or not.
 intercept A single logical for whether the given model has an intercept term or not.
 na.action Information returned by [`'model.frame'`] on the special handling of `'NA'`s.
 call A matched call.
 terms A [`'terms'`] object used.
 aliased A named logical vector showing if the original coefficients are aliased.

Examples

```
showClass("SummaryLM")
```

SummaryQGLM-class *SummaryQGLM class*

Description

S4 class for a summary of **QGLM** objects. It inherits from **SummaryGLM** class.

Slots

family A ['family'] object used.

dispersion A single numeric for the estimated dispersion parameter.

statistic A single numeric of minus twice the (constrained) empirical log-likelihood ratio for the overall test.

df A single integer for the degrees of freedom of the statistic.

convergence A single logical for the convergence status of the constrained minimization.

sigTests A numeric matrix of the results of significance tests.

weighted A single logical for whether the given model is weighted or not.

intercept A single logical for whether the given model has an intercept term or not.

na.action Information returned by ['model.frame'] on the special handling of 'NA's.

call A matched call.

terms A ['terms'] object used.

aliased A named logical vector showing if the original coefficients are aliased.

Examples

```
showClass("SummaryQGLM")
```

thiamethoxam *Thiamethoxam applications in squash crops*

Description

A dataset on the effect of the thiamethoxam application method and plant variety on bees.

Usage

```
data("thiamethoxam")
```


Format

A data frame with 55 observations and 11 variables:

trt Treatment.

var Variety.

rep Replicate.

fruit Average fruit number per plant.

avg_mass Individual Fruit mass average (g).

mass Fruit mass per plant (g).

yield Yield (4 plants).

visit Bee visits per plot.

foliage Proportion of foliage consumed by striped cucumber beetle.

scb Striped cucumber beetle per plant.

defoliation Defoliation percentage.

Source

Obregon D, Pederson G, Taylor A, Poveda K (2022). “The Pest Control and Pollinator Protection Dilemma: The Case of Thiamethoxam Prophylactic Applications in Squash Crops.” *PLOS ONE*, 17(5), 1–18. doi:10.1371/journal.pone.0267984.

Examples

```
data("thiamethoxam")
thiamethoxam
```

weights

Model weights

Description

Extracts weights from model objects. The weights are re-scaled to up to the total number of observations in the fitting procedure.

Usage

```
## S4 method for signature 'EL'
weights(object, ...)
```

Arguments

object An object that inherits from [EL](#).

... Further arguments passed to methods.

Value

A numeric vector of the re-scaled weights.

References

Glenn N, Zhao Y (2007). “Weighted Empirical Likelihood Estimates and Their Robustness Properties.” *Computational Statistics & Data Analysis*, 51(10), 5130–5141. doi:[10.1016/j.csda.2006.07.032](https://doi.org/10.1016/j.csda.2006.07.032).

See Also

[EL](#)

Examples

```
data("airquality")
x <- airquality$Wind
w <- airquality$Day
fit <- el_mean(x, par = 10, weights = w)
weights(fit)
```

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