Package 'glmtoolbox'

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Type Package

Title Set of Tools to Data Analysis using Generalized Linear Models

Version 0.1.3

Description Set of tools to the statistical analysis of data using: (1) normal linear models; (2) generalized linear models; (3) negative binomial regression models as alternative to the Poisson regression models under the presence of overdispersion; (4) beta-binomial regression models as alternative to the binomial regression models under the presence of overdispersion; (5) generalized estimating equations for cluster correlated data.

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Imports methods, stats, utils, graphics, numDeriv, Rfast, splines, Formula

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R topics documented:

AGPC *AGPC for Generalized Estimating Equations*

Description

Computes the Akaike-type penalized Gaussian pseudo-likelihood criterion (AGPC) for one or more objects of the class glmgee.

Usage

```
AGPC(..., k = 2, verbose = TRUE)
```

Arguments

`...`	one or several objects of the class *glmgee*.
`k`	an (optional) non-negative value giving the magnitude of the penalty. By default, `k` is set to be 2.
`verbose`	an (optional) logical switch indicating if should the report of results be printed. By default, `verbose` is set to be TRUE.

Details

If k is set to be 0 then the AGPC reduces to the Gaussian pseudo-likelihood criterion (GPC), proposed by Carey and Wang (2011), which corresponds to the logarithm of the multivariate normal density function.

Value

A `data.frame` with the values of the gaussian pseudo-likelihood, the number of parameters in the linear predictor plus the number of parameters in the correlation matrix, and the value of AGPC for each *glmgee* object in the input.

References

Carey, V.J. and Wang, Y.-G. (2011) Working covariance model selection for generalized estimating equations. *Statistics in Medicine* 30, 3117-3124.

Zhu, X. and Zhu, Z. (2013) Comparison of Criteria to Select Working Correlation Matrix in Generalized Estimating Equations. *Chinese Journal of Applied Probability and Statistics* 29, 515-530.

Fu, L. and Hao, Y. and Wang, Y.-G. (2018) Working correlation structure selection in generalized estimating equations. *Computational Statistics* 33, 983-996.

See Also

QIC, CIC, RJC, GHYC, SGPC

Examples

```
###### Example 1: Effect of ozone-enriched atmosphere on growth of sitka spruces
mod1 <- size ~ poly(days,4) + treat
fit1 <- glmgee(mod1, id=tree, family=Gamma("log"), data=spruces)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Stationary-M-dependent(2)")
fit4 <- update(fit1, corstr="Exchangeable")
AGPC(fit1, fit2, fit3, fit4)

###### Example 2: Treatment for severe postnatal depression
mod2 <- depressd ~ visit + group
fit1 <- glmgee(mod2, id=subj, family=binomial("logit"), data=depression)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Stationary-M-dependent(2)")
fit4 <- update(fit1, corstr="Exchangeable")
AGPC(fit1, fit2, fit3, fit4)

###### Example 3: Treatment for severe postnatal depression (2)
mod3 <- dep ~ visit*group
fit1 <- glmgee(mod3, id=subj, family=gaussian("identity"), data=depression)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Exchangeable")
AGPC(fit1, fit2, fit3)
```

anova.glmgee *Comparison of nested Generalized Estimating Equations*

Description

Allows to compare nested generalized estimating equations using the Wald and generalized score tests.

Usage

```
## S3 method for class 'glmgee'
anova(
  object,
  ...,
  test = c("wald", "score"),
  verbose = TRUE,
  varest = c("robust", "df-adjusted", "model", "bias-corrected")
)
```

Arguments

object	an object of the class *glmgee*.
...	another objects of the class glmgee which are obtained from the fit of generalized estimating equations.
test	an (optional) character string indicating the required test. The available options are: Wald ("wald") and generalized score ("score") tests. By default, test is set to be "wald".
verbose	an (optional) logical switch indicating if should the report of results be printed. By default, verbose is set to be TRUE.
varest	an (optional) character string indicating the type of estimator which should be used to the variance-covariance matrix of the interest parameters in the Wald test. The available options are: robust sandwich-type estimator ("robust"), degrees-of-freedom-adjusted estimator ("df-adjusted"), bias-corrected estimator ("bias-corrected"), and the model-based or naive estimator ("model"). By default, varest is set to be "robust". See vcov.glmgee.

Value

A matrix with three columns which contains the following:

- Chi: The value of the statistic of the test.
- df: The number of degrees of freedom.
- Pr(>Chi): The *p*-value of the test computed using the Chi-square distribution.

References

Rotnitzky, A. and Jewell, P. (1990) Hypothesis Testing of Regression Parameters in Semiparametric Generalized Linear Models for Cluster Correlated Data. *Biometrika* 77, 485-497.

Boos, D.D. (1992) On Generalized Score Tests. *The American Statistician* 46, 327-333.

Boos, D. (1992) On Generalized Score Tests. *American Statistician* 46, 327–33.

Rotnitzky, A. and Jewell, N.P. (1990). Hypothesis Testing of Regression Parameters in Semiparametric Generalized Linear Models for Cluster Correlated Data. *Biometrika* 77, 485-497.

Examples

```
###### Example 1: Effect of ozone-enriched atmosphere on growth of sitka spruces
mod <- size ~ poly(days,4)
fit1 <- glmgee(mod, id=tree, family=Gamma("log"), data=spruces, corstr="AR-1")
fit2 <- update(fit1, . ~ . + treat)
fit3 <- update(fit2, . ~ . + poly(days,4):treat)
anova(fit1,fit2,fit3,test="wald")
anova(fit3,test="wald")
anova(fit1,fit2,fit3,test="score")
anova(fit3,test="score")

###### Example 2: Treatment for severe postnatal depression
mod2 <- depressd ~ group
fit1 <- glmgee(mod2, id=subj, family=binomial("logit"), corstr="AR-1", data=depression)
fit2 <- update(fit1, . ~ . + visit)
fit3 <- update(fit2, . ~ . + group:visit)
anova(fit1,fit2,fit3,test="wald")
anova(fit3,test="wald")
anova(fit1,fit2,fit3,test="score")
anova(fit3,test="score")

###### Example 3: Treatment for severe postnatal depression (2)
mod3 <- dep ~ group
fit1 <- glmgee(mod3, id=subj, family=gaussian("identity"), corstr="AR-1", data=depression)
fit2 <- update(fit1, . ~ . + visit)
fit3 <- update(fit2, . ~ . + visit:group)
anova(fit1,fit2,fit3,test="wald")
anova(fit3,test="wald")
anova(fit1,fit2,fit3,test="score")
anova(fit3,test="score")
```

`anova.overglm` *Comparison of nested models for alternatives to the Poisson and Binomial Regression Models under the presence of Overdispersion.*

Description

Allows to compare nested models for regression models based on the negative binomial, beta-binomial, and random-clumped binomial distributions, which are alternatives to the Poisson and

binomial regression models under the presence of overdispersion. The comparisons are performed by using the Wald, score, gradient or likelihood ratio tests.

Usage

```
## S3 method for class 'overglm'
anova(object, ..., test = c("wald", "lr", "score", "gradient"), verbose = TRUE)
```

Arguments

`object`	an object of the class *overglm*.
`...`	another objects of the class *overglm*.
`test`	an (optional) character string which allows to specify the required test. The available options are: Wald ("wald"), Rao's score ("score"), likelihood ratio ("lr") and Terrell's gradient ("gradient") tests. By default, `test` is set to be "wald".
`verbose`	an (optional) logical indicating if should the report of results be printed. By default, `verbose` is set to be TRUE.

Value

A matrix with the following three columns:

`Chi`	The value of the statistic of the test,
`Df`	The number of degrees of freedom,
`Pr(>Chi)`	The *p*-value of the `test`-type test computed using the Chi-square distribution,

References

Buse, A. (1982) The Likelihood Ratio, Wald, and Lagrange Multiplier Tests: An Expository Note. *The American Statistician* 36, 153-157.

Terrell, G.R. (2002) The gradient statistic. *Computing Science and Statistics* 34, 206–215.

Examples

```
## Example 1: Self diagnozed ear infections in swimmers
fit1 <- overglm(infections ~ frequency, family="nb1(log)", data=swimmers)
fit2 <- update(fit1, . ~ . + location)
fit3 <- update(fit2, . ~ . + age)
fit4 <- update(fit3, . ~ . + gender)
anova(fit1, fit2, fit3, fit4, test="wald")
anova(fit1, fit2, fit3, fit4, test="score")
anova(fit1, fit2, fit3, fit4, test="lr")
anova(fit1, fit2, fit3, fit4, test="gradient")

## Example 2: Agents to stimulate cellular differentiation
```

```
fit1 <- overglm(cbind(cells,200-cells) ~ tnf, family="bb(logit)", data=cellular)
fit2 <- update(fit1, . ~ . + ifn)
fit3 <- update(fit2, . ~ . + tnf:ifn)
anova(fit1, fit2, fit3, test="wald")
anova(fit1, fit2, fit3, test="score")
anova(fit1, fit2, fit3, test="lr")
anova(fit1, fit2, fit3, test="gradient")
```

`anova.zeroinflation` *Comparison of nested models for Regression Models to deal with Zero-Excess in Count Data*

Description

Allows to compare nested models for regression models used to deal with zero-excess in count data. The comparisons are performed by using the Wald, score, gradient or likelihood ratio tests.

Usage

```
## S3 method for class 'zeroinflation'
anova(
  object,
  ...,
  test = c("wald", "lr", "score", "gradient"),
  verbose = TRUE,
  submodel = c("counts", "zeros")
)
```

Arguments

`object`	an object of the class *zeroinflation*.
`...`	another objects of the class *zeroinflation*.
`test`	an (optional) character string which allows to specify the required test. The available options are: Wald ("wald"), Rao's score ("score"), likelihood ratio ("lr") and Terrell's gradient ("gradient") tests. By default, `test` is set to be "wald".
`verbose`	an (optional) logical indicating if should the report of results be printed. By default, `verbose` is set to be TRUE.
`submodel`	an (optional) character string which allows to specify the model: "counts" or "zeros". By default, `submodel` is set to be "counts".

Value

A matrix with the following three columns:

- `Chi`: The value of the statistic of the test.
- `Df`: The number of degrees of freedom.
- `Pr(>Chi)`: The *p*-value of the test *test* computed using the Chi-square distribution.

References

Buse, A. (1982) The Likelihood Ratio, Wald, and Lagrange Multiplier Tests: An Expository Note. *The American Statistician* 36, 153-157.

Terrell, G.R. (2002) The gradient statistic. *Computing Science and Statistics* 34, 206–215.

Examples

```
####### Example 1: Article production by graduate students in biochemistry PhD programs
bioChemists <- pscl::bioChemists
#fit1 <- zeroinf(art ~ fem + kid5 + ment | ment, family="nb1(log)", data = bioChemists)
#anova(fit1,test="wald")
#anova(fit1,test="lr")
#anova(fit1,test="score")
#anova(fit1,test="gradient")

#fit1a <- zeroalt(art ~ fem + kid5 + ment, family="nb1(log)", data = bioChemists)
#anova(fit1a,submodel="zeros",test="wald")
#anova(fit1a,submodel="zeros",test="lr")
#anova(fit1a,submodel="zeros",test="score")
#anova(fit1a,submodel="zeros",test="gradient")
```

---

anova2 *Comparison of nested Generalized Linear Models*

Description

Allows to compare nested generalized linear models using Wald, score, gradient, and likelihood ratio tests.

Usage

```
anova2(
  object,
  ...,
  test = c("wald", "lr", "score", "gradient"),
  verbose = TRUE
)
```

Arguments

`object`	an object of the class glm which is obtained from the fit of a generalized linear model.
`...`	another objects of the class glm which are obtained from the fit of generalized linear models.
`test`	an (optional) character string indicating the required type of test. The available options are: Wald ("wald"), Rao's score ("score"), Terrell's gradient ("gradient"), and likelihood ratio ("lr") tests. By default, `test` is set to be "wald".

`verbose` an (optional) logical indicating if should the report of results be printed. By default, `verbose` is set to be TRUE.

Details

The Wald, Rao's score and Terrell's gradient tests are performed using the expected Fisher information matrix.

Value

A matrix with three columns which contains the following:

- `Chi`: The value of the statistic of the test.
- `Df`: The number of degrees of freedom.
- `Pr(>Chi)`: The *p*-value of the test computed using the Chi-square distribution.

References

Buse, A. (1982) The Likelihood Ratio, Wald, and Lagrange Multiplier Tests: An Expository Note. *The American Statistician* 36, 153-157.

Terrell, G.R. (2002) The gradient statistic. *Computing Science and Statistics* 34, 206 – 215.

Examples

```
## Example 1
Auto <- ISLR::Auto
fit1 <- glm(mpg ~ weight, family=inverse.gaussian("log"), data=Auto)
fit2 <- update(fit1, . ~ . + horsepower)
fit3 <- update(fit2, . ~ . + horsepower:weight)
anova2(fit1, fit2, fit3, test="lr")
anova2(fit1, fit2, fit3, test="score")
anova2(fit1, fit2, fit3, test="wald")
anova2(fit1, fit2, fit3, test="gradient")

## Example 2
burn1000 <- aplore3::burn1000
mod <- death ~ age + tbsa + inh_inj
fit1 <- glm(mod, family=binomial("logit"), data=burn1000)
fit2 <- update(fit1, . ~ . + inh_inj + age*inh_inj + tbsa*inh_inj)
anova2(fit1, fit2, test="lr")
anova2(fit1, fit2, test="score")
anova2(fit1, fit2, test="wald")
anova2(fit1, fit2, test="gradient")

## Example 3
fit <- glm(lesions ~ 1 + time, family=poisson("log"), data=aucuba)
anova2(fit, test="lr")
anova2(fit, test="score")
anova2(fit, test="wald")
anova2(fit, test="gradient")
```

aucuba *Lesions of Aucuba mosaic virus*

Description

The investigators counted the number of lesions of *Aucuba mosaic* virus developing after exposure to X rays for various times. See Snedecor and Cochran (1980, page 404).

Usage

```
data(aucuba)
```

Format

A data frame with 7 rows and 2 variables:

time a numeric vector giving the minutes of exposure.

lesions a numeric vector giving the counts of lesions, in hundreds.

References

Snedecor, G.W. and Cochran, W.G. (1989) *Statistical Methods, Eight Edition*, Iowa State University Press, Ames.

Examples

```
barplot(lesions ~ time, col="red", data=aucuba)
```

bladder *Bladder cancer in mice*

Description

Female mice were continuously fed dietary concentrations of 2-Acetylaminofluorene (2-AAF), a carcinogenic and mutagenic derivative of fluorene. Serially sacrificed, dead or moribund mice were examined for tumors and dates of deaths were recorded. These data consist of the incidences of bladder neoplasms in the mice observed during 33 months.

Usage

```
data(bladder)
```

Format

A data frame with 8 rows and 3 variables:

dose a numeric vector giving the dose, in parts per 10^4, of 2-AAF.

exposed a numeric vector giving the number of mice exposed to each dose of 2-AAF.

cancer a numeric vector giving the number of mice with bladder cancer for each dose of 2-AAF.

References

Zhang, H. and Zelterman, D. (1999) Binary Regression for Risks in Excess of Subject-Specific Thresholds. *Biometrics* 55, 1247-1251.

See Also

liver

Examples

```
barplot(100*cancer/exposed ~ dose, beside=TRUE, data=bladder, col="red",
        xlab="Dose of 2-AAF", ylab="% of mice with bladder cancer")
```

---

brains *Mammal brain and body weights*

Description

These data corresponds to the (average) body weight and the (average) brain weight for sixty-two species of mammals.

Usage

```
data(brains)
```

Format

A data frame with 62 rows and 3 variables:

Specie a character string giving the species name.

BrainWt a numeric vector indicating the average brain weight, in grams.

BodyWt a numeric vector indicating the average body weight, in kilograms.

References

Allison, T. and Cicchetti, D. (1976). Sleep in mammals: Ecology and constitutional correlates. *Science* 194, 732-734.

Weisberg, S. (2005). *Applied Linear Regression*, 3rd edition. Wiley, New York.

Examples

```
with(brains, plot(log(BodyWt),log(BrainWt),pch=20,
               xlab="log(Body Weight)",ylab="log(Brain Weight)"))
```

`cellular` *Agents to stimulate cellular differentiation*

Description

In a biomedical study of the immuno-activating ability of two agents, TNF (tumor necrosis factor) and IFN (interferon), to induce cell differentiation, the number of cells that exhibited markers of differentiation after exposure to TNF and IFN was recorded. At each of the 16 dose combinations of TNF/INF, 200 cells were examined. The main question is whether the two agents stimulate cell differentiation synergistically or independently.

Usage

```
data(cellular)
```

Format

A data frame with 16 rows and 3 variables:

cells a numeric vector giving the number of cells that exhibited markers of differentiation after exposure to the dose of the two agents

tnf a numeric vector giving the dose (U/ml) of TNF

ifn a numeric vector giving the dose (U/ml) of IFN

References

Piegorsch, W.W. and Weinberg, C.R. and Margolin, B.H. (1988) Exploring simple independent action in multifactor tables of proportions. *Biometrics* 44, 595-603.

Vanegas, L.H. and Rondon, L.M. (2020) A data transformation to deal with constant under/over-dispersion in binomial and poisson regression models. *Journal of Statistical Computation and Simulation* 90, 1811-1833.

Examples

```
barplot(100*cells/200 ~ ifn + tnf, beside=TRUE, data=cellular, col=terrain.colors(4),
        xlab="Dose of TNF", ylab="% of cells with markers of differentiation")
legend(-3, 97, c("0","4","20","100"), fill=terrain.colors(4), bty="n", cex=0.9,
       title="Dose of IFN", x.intersp=0.2, y.intersp=1)
```

`cholecystectomy` *Shoulder Pain after Laparoscopic Cholecystectomy*

Description

Inflation of the abdomen during laparoscopic cholecystectomy (removal of the gallbladder) separates the liver from the diaphragm and places strain on the attachments that connect both. This strain is felt as referred pain in the shoulder. Suction to remove residual gas may reduce shoulder pain. There were 22 subjects randomized in the active group (with abdominal suction) and 19 subjects randomized in the control group (without abdominal suction). After laparoscopic surgery, patients were asked to rate their shoulder pain on a visual analog scale morning and afternoon for three days after the operation (a total of six different times). The scale was coded into five ordered categories where a pain score of 1 indicated "low pain" and a score of 5 reflected "high pain". See Jorgensen et al. (1995), Lumley (1996), Morel and Nagaraj (2012, page 319).

Usage

```
data(cholecystectomy)
```

Format

A data frame with 246 rows and 7 variables:

id a numeric vector with the identifier of the patient.

treatment a factor indicating the treatment received by the patient: abdominal suction ("A") and placebo ("P").

gender a factor indicating the gender of the patient: female ("F") and male ("M").

age a numeric vector indicating the age of the patient, in years.

time a numeric vector indicating the occasion the patient was asked to rate their shoulder pain after the laparoscopic surgery: integers from 1 to 6.

pain a numeric vector indicating the shoulder pain rated by the patient on a scale coded into five ordered categories, where 1 indicated "low pain" and 5 reflected "high pain".

pain2 a numeric vector indicating the shoulder pain rated by the patient and coded as 1 for the two first categories of pain and 0 for other cases.

References

Jorgensen, J.O. and Gillies, R.B. and Hunt, D.R. and Caplehorn, J.R.M. and Lumley, T. (1995) A simple and effective way to reduce postoperative pain after laparoscopic cholecystectomy. *Australian and New Zealand Journal of Surgery* 65, 466–469.

Lumley, T. (1996) Generalized Estimating Equations for Ordinal Data: A Note on Working Correlation Structures. *Biometrics* 52, 354–361.

Morel, J.G. and Nagaraj, N.K. (2012) *Overdispersion Models in SAS*. SAS Institute Inc., Cary, North Carolina, USA.

Examples

```
out <- aggregate(pain2 ~ treatment + time, data=cholecystectomy, mean)
barplot(100*pain2 ~ treatment + time, beside=TRUE, data=out, xlab="Time",
        col=c("yellow","blue"), ylab="% of patients with \"low\" pain")
legend(-1, 98, c("Placebo","Abdominal\n suction"), fill=c("yellow","blue"),
       bty="n", cex=0.6, x.intersp=0.2, y.intersp=1)
```

`CIC` *Correlation Information Criterion for Generalized Estimating Equations*

Description

Computes the Correlation Information Criterion (CIC) for one or more objects of the class glmgee.

Usage

```
CIC(..., verbose = TRUE)
```

Arguments

`...`	one or several objects of the class *glmgee*.
`verbose`	an (optional) logical switch indicating if should the report of results be printed. By default, `verbose` is set to be TRUE.

Value

A `data.frame` with the values of the CIC for each *glmgee* object in the input.

References

Hin, L.-Y. and Wang, Y.-G. (2009) Working-Correlation-Structure Identification in Generalized Estimating Equations. *Statistics in Medicine*, 28, 642-658.

Hin, L.-Y. and Carey, V.J. and Wang, Y.-G. (2007) Criteria for Working–Correlation–Structure Selection in GEE: Assessment via Simulation. *The American Statistician* 61, 360–364.

See Also

QIC, GHYC, RJC, AGPC, SGPC

Examples

```
###### Example 1: Effect of ozone-enriched atmosphere on growth of sitka spruces
mod1 <- size ~ poly(days,4) + treat
fit1 <- glmgee(mod1, id=tree, family=Gamma("log"), data=spruces)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Stationary-M-dependent(2)")
fit4 <- update(fit1, corstr="Exchangeable")
CIC(fit1, fit2, fit3, fit4)

###### Example 2: Treatment for severe postnatal depression
mod2 <- depressd ~ visit + group
fit1 <- glmgee(mod2, id=subj, family=binomial("logit"), data=depression)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Stationary-M-dependent(2)")
fit4 <- update(fit1, corstr="Exchangeable")
CIC(fit1, fit2, fit3, fit4)

###### Example 3: Treatment for severe postnatal depression (2)
mod3 <- dep ~ visit*group
fit1 <- glmgee(mod3, id=subj, family=gaussian("identity"), data=depression)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Exchangeable")
CIC(fit1, fit2, fit3)
```

---

confint2 *Confidence Intervals for Generalized Linear Models*

Description

Computes confidence intervals based on Wald, likelihood-ratio, Rao's score or Terrell's gradient tests for a generalized linear model.

Usage

```
confint2(
  model,
  level = 0.95,
  test = c("wald", "lr", "score", "gradient"),
  digits = 5,
  verbose = TRUE
)
```

Arguments

`model`	an object of the class *glm*.
`level`	an (optional) value indicating the required confidence level. By default, `level` is set to be 0.95.

test	an (optional) character string indicating the required type of test. The available options are: Wald ("wald"), Rao's score ("score"), Terrell's gradient ("gradient"), and likelihood ratio ("lr") tests. By default, test is set to be "wald".
digits	an (optional) integer value indicating the number of decimal places to be used. By default, digits is set to be 5.
verbose	an (optional) logical indicating if should the report of results be printed. By default, verbose is set to be TRUE.

Details

The approximate 100(level)% confidence interval for β based on the test test is the set of values of β_0 for which the hypothesis H_0: $\beta = \beta_0$ versus H_1: $\beta! = \beta_0$ is not rejected at the approximate significance level of 100(1-level)%. The Wald, Rao's score and Terrell's gradient tests are performed using the expected Fisher information matrix.

Value

A matrix with so many rows as parameters in the linear predictor and two columns: "Lower limit" and "Upper limit".

References

Buse, A. (1982) The Likelihood Ratio, Wald, and Lagrange Multiplier Tests: An Expository Note. *The American Statistician* 36, 153-157.

Terrell, G.R. (2002) The gradient statistic. *Computing Science and Statistics* 34, 206 – 215.

Examples

```
###### Example 1: Fuel consumption of automobiles
Auto <- ISLR::Auto
fit1 <- glm(mpg ~ weight*horsepower, family=inverse.gaussian("log"), data=Auto)
confint2(fit1, test="lr")
confint2(fit1, test="score")

###### Example 2: Patients with burn injuries
burn1000 <- aplore3::burn1000
burn1000 <- within(burn1000, death <- factor(death, levels=c("Dead","Alive")))
fit2 <- glm(death ~ age*inh_inj + tbsa*inh_inj, family=binomial("logit"), data=burn1000)
confint2(fit2, test="lr")
confint2(fit2, test="gradient")
```

cooks.distance.glmgee *Cook's Distance for Generalized Estimating Equations*

Description

Produces an approximation, better known as the *one-step aproximation*, of the Cook's distance, which is aimed to measure the effect on the estimates of the parameters in the linear predictor of deleting each cluster/observation in turn. This function also can produce a cluster/observation-index plot of the Cook's distance for all parameters in the linear predictor or for some subset of them (via the argument `coefs`).

Usage

```
## S3 method for class 'glmgee'
cooks.distance(
  model,
  method = c("Preisser-Qaqish", "full"),
  level = c("clusters", "observations"),
  plot.it = FALSE,
  coefs,
  identify,
  varest = c("robust", "df-adjusted", "model", "bias-corrected"),
  ...
)
```

Arguments

`model`	an object of class *glmgee*.
`method`	an (optional) character string indicating the method of calculation for the *one-step approximation*. The options are: the *one-step approximation* described by Preisser and Qaqish (1996) in which the working-correlation matrix is assumed to be known ("Preisser-Qaqish"); and the "authentic" *one-step approximation* ("full"). By default, `method` is set to be "Preisser-Qaqish".
`level`	an (optional) character string indicating the level for which the Cook's distance is required. The options are: cluster-level ("clusters") and observation-level ("observations"). By default, `level` is set to be "clusters".
`plot.it`	an (optional) logical indicating if the plot of Cook's distance is required or just the data matrix in which that plot is based. By default, `plot.it` is set to be FALSE.
`coefs`	an (optional) character string which (partially) match with the names of some of the parameters in the linear predictor.
`identify`	an (optional) integer indicating the number of clusters to identify on the plot of Cook's distance. This is only appropriate if `plot.it=TRUE`.

varest	an (optional) character string indicating the type of estimator which should be used to the variance-covariance matrix of the interest parameters. The available options are: robust sandwich-type estimator ("robust"), degrees-of-freedom-adjusted estimator ("df-adjusted"), bias-corrected estimator ("bias-corrected"), and the model-based or naive estimator ("model"). By default, varest is set to be "robust".
...	further arguments passed to or from other methods. If plot.it=TRUE then ... may be used to include graphical parameters to customize the plot. For example, col, pch, cex, main, sub, xlab, ylab.

Details

The Cook's distance consists of the *distance* between two estimates of the parameters in the linear predictor using a metric based on the (estimate of the) variance-covariance matrix. For the cluster-level, the first one set of estimates is computed from a dataset including all clusters/observations, and the second one is computed from a dataset in which the *i*-th cluster is excluded. To avoid computational burden, the second set of estimates is replaced by its *one-step approximation*. See the dfbeta.glmgee documentation.

Value

A matrix as many rows as clusters/observations in the sample and one column with the values of the Cook's distance.

References

Pregibon, D. (1981). Logistic regression diagnostics. *The Annals of Statistics* 9, 705-724.

Preisser, J.S. and Qaqish, B.F. (1996) Deletion diagnostics for generalised estimating equations. *Biometrika* 83, 551–562.

Hammill, B.G. and Preisser, J.S. (2006) A SAS/IML software program for GEE and regression diagnostics. *Computational Statistics & Data Analysis* 51, 1197-1212.

Examples

```
###### Example 1: Effect of ozone-enriched atmosphere on growth of sitka spruces
mod1 <- size ~ poly(days,4) + treat
fit1 <- glmgee(mod1, id=tree, family=Gamma("log"), data=spruces, corstr="AR-1")

### Cook's distance for all parameters in the linear predictor
cooks.distance(fit1, method="full", plot.it=TRUE, col="red", lty=1, lwd=1, cex=0.8,
               col.lab="blue", col.axis="blue", col.main="black", family="mono")

### Cook's distance for the parameter associated to the variable 'treat'
cooks.distance(fit1, coef="treat", method="full", plot.it=TRUE, col="red", lty=1,
               lwd=1, col.lab="blue", col.axis="blue", col.main="black", cex=0.8)

###### Example 2: Treatment for severe postnatal depression
mod2 <- depressd ~ visit + group
fit2 <- glmgee(mod2, id=subj, family=binomial("logit"), corstr="AR-1", data=depression)
```

```
### Cook's distance for all parameters in the linear predictor
cooks.distance(fit2, method="full", plot.it=TRUE, col="red", lty=1, lwd=1, cex=0.8,
               col.lab="blue", col.axis="blue", col.main="black", family="mono")

### Cook's distance for the parameter associated to the variable 'group'
cooks.distance(fit2, coef="group", method="full", plot.it=TRUE, col="red", lty=1,
               lwd=1, col.lab="blue", col.axis="blue", col.main="black", cex=0.8)
```

`cooks.distance.overglm` *Cook's Distance for alternatives to the Poisson and Binomial Regression Models under the presence of Overdispersion*

Description

Produces an approximation, better known as the *one-step approximation*, of the Cook's distance, which is aimed to measure the effect on the estimates of the parameters in the linear predictor of deleting each observation in turn. This function also can produce an index plot of the Cook's distance for all parameters in the linear predictor or for some subset of them (via the argument `coefs`).

Usage

```
## S3 method for class 'overglm'
cooks.distance(model, plot.it = FALSE, coefs, identify, ...)
```

Arguments

`model`	an object of class *overglm*.
`plot.it`	an (optional) logical indicating if the plot is required or just the data matrix in which that plot is based. By default, `plot.it` is set to be FALSE.
`coefs`	an (optional) character string which (partially) match with the names of some model parameters.
`identify`	an (optional) integer indicating the number of individuals to identify on the plot of the Cook's distance. This is only appropriate if `plot.it=TRUE`.
`...`	further arguments passed to or from other methods. If `plot.it=TRUE` then `...` may be used to include graphical parameters to customize the plot. For example, `col`, `pch`, `cex`, `main`, `sub`, `xlab`, `ylab`.

Details

The Cook's distance consists of the *distance* between two estimates of the parameters in the linear predictor using a metric based on the (estimate of the) variance-covariance matrix. The first one set of estimates is computed from a dataset including all individuals, and the second one is computed from a dataset in which the *i*-th individual is excluded. To avoid computational burden, the second set of estimates is replaced by its *one-step approximation*. See the dfbeta.overglm documentation.

Value

A matrix as many rows as individuals in the sample and one column with the values of the Cook's distance.

Examples

```
###### Example 1: Self diagnozed ear infections in swimmers
fit1 <- overglm(infections ~ frequency + location, family="nb1(log)", data=swimmers)

### Cook's distance for all parameters in the linear predictor
cooks.distance(fit1, plot.it=TRUE, col="red", lty=1, lwd=1, col.lab="blue",
               col.axis="blue", col.main="black", family="mono", cex=0.8)

### Cook's distance just for the parameter associated with 'frequency'
cooks.distance(fit1, plot.it=TRUE, coef="frequency", col="red", lty=1, lwd=1,
   col.lab="blue", col.axis="blue", col.main="black", family="mono", cex=0.8)

###### Example 2: Article production by graduate students in biochemistry PhD programs
bioChemists <- pscl::bioChemists
fit2 <- overglm(art ~ fem + kid5 + ment, family="nb1(log)", data = bioChemists)

### Cook's distance for all parameters in the linear predictor
cooks.distance(fit2, plot.it=TRUE, col="red", lty=1, lwd=1, col.lab="blue",
               col.axis="blue", col.main="black", family="mono", cex=0.8)

### Cook's distance just for the parameter associated with 'fem'
cooks.distance(fit2, plot.it=TRUE, coef="fem", col="red", lty=1, lwd=1,
   col.lab="blue", col.axis="blue", col.main="black", family="mono", cex=0.8)

###### Example 3: Agents to stimulate cellular differentiation
fit3 <- overglm(cbind(cells,200-cells) ~ tnf + ifn, family="bb(logit)", data=cellular)

### Cook's distance for all parameters in the linear predictor
cooks.distance(fit3, plot.it=TRUE, col="red", lty=1, lwd=1, col.lab="blue",
               col.axis="blue", col.main="black", family="mono", cex=0.8)

### Cook's distance just for the parameter associated with 'tnf'
cooks.distance(fit3, plot.it=TRUE, coef="tnf", col="red", lty=1, lwd=1,
  col.lab="blue", col.axis="blue", col.main="black", family="mono", cex=0.8)
```

---

cooks.distance.zeroinflation

Cook's Distance for Regression Models to deal with Zero-Excess in Count Data

---

Description

Produces an approximation, better known as the *one-step approximation*, of the Cook's distance, which is aimed to measure the effect on the estimates of the parameters in the linear predictor

of deleting each observation in turn. This function also can produce an index plot of the Cook's distance for all parameters in the linear predictor or for some subset of them (via the argument `coefs`).

Usage

```
## S3 method for class 'zeroinflation'
cooks.distance(
  model,
  submodel = c("counts", "zeros", "full"),
  plot.it = FALSE,
  coefs,
  identify,
  ...
)
```

Arguments

`model`	an object of class *zeroinflation*.
`submodel`	an (optional) character string which allows to specify the model: "counts", "zeros" or "full". By default, `submodel` is set to be "counts".
`plot.it`	an (optional) logical indicating if the plot is required or just the data matrix in which that plot is based. By default, `plot.it` is set to be FALSE.
`coefs`	an (optional) character string which (partially) match with the names of some model parameters.
`identify`	an (optional) integer indicating the number of individuals to identify on the plot of the Cook's distance. This is only appropriate if `plot.it=TRUE`.
`...`	further arguments passed to or from other methods. If `plot.it=TRUE` then `...` may be used to include graphical parameters to customize the plot. For example, `col`, `pch`, `cex`, `main`, `sub`, `xlab`, `ylab`.

Details

The Cook's distance consists of the *distance* between two estimates of the parameters in the linear predictor using a metric based on the (estimate of the) variance-covariance matrix. The first one set of estimates is computed from a dataset including all individuals, and the second one is computed from a dataset in which the *i*-th individual is excluded. To avoid computational burden, the second set of estimates is replaced by its *one-step approximation*. See the dfbeta.zeroinflation documentation.

Value

A matrix as many rows as individuals in the sample and one column with the values of the Cook's distance.

Examples

```
####### Example 1: Self diagnozed ear infections in swimmers
fit <- zeroinf(infections ~ frequency + location, family="nb1(log)", data=swimmers)

### Cook's distance for all parameters in the "counts" model
cooks.distance(fit, submodel="counts", plot.it=TRUE, col="red", lty=1, lwd=1,
         col.lab="blue", col.axis="blue", col.main="black", family="mono", cex=0.8)

### Cook's distance for all parameters in the "zeros" model
cooks.distance(fit, submodel="zeros", plot.it=TRUE, col="red", lty=1, lwd=1,
         col.lab="blue", col.axis="blue", col.main="black", family="mono", cex=0.8)
```

---

depression *Treatment for severe postnatal depression*

Description

These data arose from a study on the efficacy of oestrogen give transdermally for treatment of severe postnatal depression. Women with major depression were randomly assigned to either a placebo control group or estrogen patch group. Prior to the treatment all women were assessed by self-ratings of depressive symptoms on the Edinburgh Postnatal Depression Scale (EPDS). The data on EPDS were collected monthly for six months once the treatment began. Higher scores on the EDPS are indicative of higher levels of depression.

Usage

```
data(depression)
```

Format

A data frame with 427 rows and 5 variables:

subj a numeric vector giving the identifier of each woman .

group a factor giving the received treatment: "placebo" or "estrogen".

visit a numeric vector giving the number of months since the treatment began, where -1 indicates the pretreatment assessment of the EDPS.

dep a numeric vector giving the value of the EDPS.

depressd a numeric vector coded as 1 when the value of the EDPS is greater than or equal to 11 and coded as 0 in other cases.

Source

https://stats.oarc.ucla.edu/spss/library/spss-librarypanel-data-analysis-using-gee/

References

Gregoire, A.J.P. and Kumar, R. and Everitt, B. and Henderson, A.F. and Studd, J.W.W. (1996) Transdermal oestrogen for treatment of severe postnatal depression, *The Lancet* 347, 930-933.

Examples

```
boxplot(dep ~ visit, data=subset(depression,group=="placebo"), at=c(0:6)-0.2,
        col="yellow", boxwex=0.3, outline=FALSE, xaxt="n", ylab="EDPS",
        xlab="Months since the treatment began", ylim=range(na.omit(depression$dep)))
boxplot(dep ~ visit, data=subset(depression,group=="estrogen"), add=TRUE,
        at=c(0:6)+0.2, col="blue", boxwex=0.3, outline=FALSE, xaxt="n")
axis(1, at=0:6, labels=c(-1,1:6))
legend(5, 29, legend=c("placebo","estrogen"), fill=c("yellow","blue"),
       bty="n", x.intersp=0.2, y.intersp=1)
```

`dfbeta.glmgee` *Dfbeta for Generalized Estimating Equations*

Description

Produces an approximation, better known as the *one-step approximation*, of the effect on the parameter estimates of deleting each cluster/observation in turn. This function also can produce an index plot of the Dfbeta Statistic for some parameters via the argument `coefs`.

Usage

```
## S3 method for class 'glmgee'
dfbeta(
  model,
  level = c("clusters", "observations"),
  method = c("Preisser-Qaqish", "full"),
  coefs,
  identify,
  ...
)
```

Arguments

`model`	an object of class *glmgee*.
`level`	an (optional) character string indicating the level for which the Dfbeta statistic is required. The options are: cluster-level ("clusters") and observation-level ("observations"). By default, `level` is set to be "clusters".
`method`	an (optional) character string indicating the method of calculation for the *one-step approximation*. The options are: the *one-step approximation* described by Preisser and Qaqish (1996) in which the working-correlation matrix is assumed to be known ("Preisser-Qaqish"); and the "authentic" *one-step approximation* ("full"). By default, `method` is set to be "Preisser-Qaqish".

coefs	an (optional) character string which (partially) match with the names of some parameters in the linear predictor.
identify	an (optional) integer indicating the number of clusters/observations to identify on the plot of the Dfbeta statistic. This is only appropriate if coefs is specified.
...	further arguments passed to or from other methods. If coefs is specified then ... may be used to include graphical parameters to customize the plot. For example, col, pch, cex, main, sub, xlab, ylab.

Details

The *one-step approximation* (with the method "full") of the estimates of the parameters in the linear predictor of a GEE when the *i*-th cluster is excluded from the dataset is given by the vector obtained as the result of the first iteration of the fitting algorithm of that GEE when it is performed using: (1) a dataset in which the *i*-th cluster is excluded; and (2) a starting value which is the solution to the same GEE but based on the dataset inluding all clusters.

Value

A matrix with so many rows as clusters/observations in the sample and so many columns as parameters in the linear predictor. For clusters, the i-th row of that matrix corresponds to the difference between the estimates of the parameters in the linear predictor using all clustersand the *one-step approximation* of those estimates when the *i*-th cluster is excluded from the dataset.

References

Pregibon, D. (1981). Logistic regression diagnostics. *The Annals of Statistics* 9, 705-724.

Preisser, J.S. and Qaqish, B.F. (1996) Deletion diagnostics for generalised estimating equations. *Biometrika* 83, 551–562.

Hammill, B.G. and Preisser, J.S. (2006) A SAS/IML software program for GEE and regression diagnostics. *Computational Statistics & Data Analysis* 51, 1197-1212.

Examples

```
###### Example 1: Effect of ozone-enriched atmosphere on growth of sitka spruces
mod1 <- size ~ poly(days,4) + treat
fit1 <- glmgee(mod1, id=tree, family=Gamma("log"), corstr="AR-1", data=spruces)
dfbs1 <- dfbeta(fit1, method="full", coefs="treat", col="red", lty=1, lwd=1, col.lab="blue",
         col.axis="blue", col.main="black", family="mono", cex=0.8, main="treat")

### Calculation by hand of dfbeta for the tree labeled by "N1T01"
onestep1 <- glmgee(mod1, id=tree, family=Gamma("log"), corstr="AR-1", data=spruces,
            start=coef(fit1), subset=c(tree!="N1T01"), maxit=1)

coef(fit1)-coef(onestep1)
dfbs1[rownames(dfbs1)=="N1T01",]

###### Example 2: Treatment for severe postnatal depression
mod2 <- depressd ~ visit + group
fit2 <- glmgee(mod2, id=subj, family=binomial("logit"), corstr="AR-1", data=depression)
```

```
dfbs2 <- dfbeta(fit2, method="full", coefs="group" ,col="red", lty=1, lwd=1, col.lab="blue",
         col.axis="blue", col.main="black", family="mono", cex=0.8, main="group")

### Calculation by hand of dfbeta for the woman labeled by "18"
onestep2 <- glmgee(mod2, id=subj, family=binomial("logit"), corstr="AR-1", data=depression,
            start=coef(fit2), subset=c(subj!=18), maxit=1)

coef(fit2)-coef(onestep2)
dfbs2[rownames(dfbs2)==18,]

###### Example 3: Treatment for severe postnatal depression (2)
mod3 <- dep ~ visit*group
fit3 <- glmgee(mod3, id=subj, family=gaussian("identity"), corstr="AR-1", data=depression)

dfbs3 <- dfbeta(fit3, method="full", coefs="visit:group" ,col="red", lty=1, lwd=1, col.lab="blue",
         col.axis="blue", col.main="black", family="mono", cex=0.8, main="visit:group")

### Calculation by hand of dfbeta for the woman labeled by "18"
onestep3 <- glmgee(mod3, id=subj, family=gaussian("identity"), corstr="AR-1", data=depression,
            start=coef(fit3), subset=c(subj!=18), maxit=1)

coef(fit3)-coef(onestep3)
dfbs3[rownames(dfbs3)==18,]
```

`dfbeta.overglm` *Dfbeta statistic for alternatives to the Poisson and Binomial Regression Models under the presence of Overdispersion.*

Description

Produces an approximation, better known as the *one-step approximation*, of the effect on the parameter estimates of deleting each individual in turn. This function also can produce an index plot of the Dfbeta statistic for some parameter chosen via the argument `coefs`.

Usage

```
## S3 method for class 'overglm'
dfbeta(model, coefs, identify, ...)
```

Arguments

`model`	an object of class *overglm*.
`coefs`	an (optional) character string which (partially) match with the names of some model parameters.
`identify`	an (optional) integer indicating the number of individuals to identify on the plot of the Dfbeta statistic. This is only appropriate if `coefs` is specified.
`...`	further arguments passed to or from other methods. If `plot.it=TRUE` then `...` may be used to include graphical parameters to customize the plot. For example, `col`, `pch`, `cex`, `main`, `sub`, `xlab`, `ylab`.

Details

The *one-step approximation* of the estimates of the parameters when the *i*-th individual is excluded from the dataset consists of the vector obtained as result of the first iteration of the Newthon-Raphson algorithm when it is performed using: (1) a dataset in which the *i*-th individual is excluded; and (2) a starting value which is the estimate of the same model but based on the dataset inluding all individuals.

Value

A matrix with so many rows as individuals in the sample and so many columns as parameters in the linear predictor. The i-th row of that matrix corresponds to the difference between the estimates of the parameters in the linear predictor using all individuals and the *one-step approximation* of those estimates when the *i*-th individual is excluded from the dataset.

References

Pregibon, D. (1981). Logistic regression diagnostics. *The Annals of Statistics*, 9, 705-724.

Examples

```
###### Example 1: Self diagnozed ear infections in swimmers
fit1 <- overglm(infections ~ frequency + location, family="nb1(log)", data=swimmers)
dfbeta(fit1, coefs="frequency", col="red", lty=1, lwd=1, col.lab="blue",
       col.axis="blue", col.main="black", family="mono", cex=0.8, main="frequency")

###### Example 2: Article production by graduate students in biochemistry PhD programs
bioChemists <- pscl::bioChemists
fit2 <- overglm(art ~ fem + kid5 + ment, family="nb1(log)", data = bioChemists)
dfbeta(fit2, coefs="fem", col="red", lty=1, lwd=1, col.lab="blue",
       col.axis="blue", col.main="black", family="mono", cex=0.8, main="fem")

###### Example 3: Agents to stimulate cellular differentiation
fit3 <- overglm(cbind(cells,200-cells) ~ tnf + ifn, family="bb(logit)", data=cellular)
dfbeta(fit3, coefs="tnf", col="red", lty=1, lwd=1, col.lab="blue",
       col.axis="blue", col.main="black", family="mono", cex=0.8, main="tnf")
```

---

dfbeta.zeroinflation *Dfbeta statistic for Regression Models to deal with Zero-Excess in Count Data*

Description

Produces an approximation, better known as the *one-step approximation*, of the effect on the parameter estimates of deleting each individual in turn. This function also can produce an index plot of the Dfbeta statistic for some parameter chosen via the argument `coefs`.

Usage

```
## S3 method for class 'zeroinflation'
dfbeta(model, submodel = c("counts", "zeros"), coefs, identify, ...)
```

Arguments

`model`	an object of class *zeroinflation*.
`submodel`	an (optional) character string which allows to specify the model: "counts" or "zeros". By default, `submodel` is set to be "counts".
`coefs`	an (optional) character string which (partially) match with the names of some model parameters.
`identify`	an (optional) integer indicating the number of individuals to identify on the plot of the Dfbeta statistic. This is only appropriate if `coefs` is specified.
`...`	further arguments passed to or from other methods. If `plot.it=TRUE` then `...` may be used to include graphical parameters to customize the plot. For example, `col`, `pch`, `cex`, `main`, `sub`, `xlab`, `ylab`.

Details

The *one-step approximation* of the estimates of the parameters when the *i*-th individual is excluded from the dataset consists of the vector obtained as result of the first iteration of the Newthon-Raphson algorithm when it is performed using: (1) a dataset in which the *i*-th individual is excluded; and (2) a starting value which is the estimate of the same model but based on the dataset inluding all individuals.

Value

A matrix with so many rows as individuals in the sample and so many columns as parameters in the linear predictor. The i-th row of that matrix corresponds to the difference between the estimates of the parameters in the linear predictor using all individuals and the *one-step approximation* of those estimates when the *i*-th individual is excluded from the dataset.

References

Pregibon, D. (1981). Logistic regression diagnostics. *The Annals of Statistics*, 9, 705-724.

Examples

```
####### Example 1: Self diagnozed ear infections in swimmers
fit <- zeroinf(infections ~ frequency + location, family="nb1(log)", data=swimmers)

dfbeta(fit, submodel="counts", coefs="frequency", col="red", lty=1, lwd=1,
       col.lab="blue", col.axis="blue", col.main="black", family="mono", cex=0.8)

dfbeta(fit, submodel="zeros", coefs="location", col="red", lty=1, lwd=1,
       col.lab="blue", col.axis="blue", col.main="black", family="mono", cex=0.8)
```

envelope *Normal QQ-plot with simulated envelope of model residuals*

Description

Generic function for building a normal QQ-plot with simulated envelope of residuals obtained from a fitted model.

Usage

```
envelope(object, ...)
```

Arguments

`object`	a fitted model object.
`...`	further arguments passed to or from other methods.

Value

A matrix with the simulated envelope and, optionally, a plot of it.

envelope.glm *Normal QQ-plot with simulated envelope of residuals in GLMs*

Description

Produces a normal QQ-plot with simulated envelope of residuals for generalized linear models.

Usage

```
## S3 method for class 'glm'
envelope(
  object,
  rep = 25,
  conf = 0.95,
  type = c("quantile", "deviance", "pearson"),
  standardized = FALSE,
  plot.it = TRUE,
  identify,
  ...
)
```

Arguments

object	an object of the class *glm*.
rep	an (optional) positive integer which allows to specify the number of replicates which should be used to build the simulated envelope. By default, rep is set to be 25.
conf	an (optional) value in the interval (0,1) indicating the confidence level which should be used to build the pointwise confidence intervals, which form the envelope. By default, conf is set to be 0.95.
type	a character string indicating the type of residuals which should be used. The available options are: randomized quantile ("quantile"), deviance ("deviance") and pearson ("pearson") residuals. By default, type is set to be "quantile".
standardized	an (optional) logical switch indicating if the residuals should be standardized by dividing by the square root of $(1 - h)$, where h is a measure of leverage. By default, standardized is set to be FALSE.
plot.it	an (optional) logical switch indicating if the normal QQ-plot with simulated envelope of residuals is required or just the data matrix in which it is based. By default, plot.it is set to be TRUE.
identify	an (optional) positive integer indicating the number of individuals to identify on the QQ-plot with simulated envelope of residuals. This is only appropriate if plot.it=TRUE.
...	further arguments passed to or from other methods. If plot.it=TRUE then ... may be used to include graphical parameters to customize the plot. For example, col, pch, cex, main, sub, xlab, ylab.

Details

The simulated envelope is builded by simulating rep independent realizations of the response variable for each individual, which is accomplished taking into account the following: (1) the model assumption about the distribution of the response variable; (2) the estimates of the parameters in the linear predictor; and (3) the estimate of the dispersion parameter. The interest model is re-fitted rep times, as each time the vector of observed responses is replaced by one of the simulated samples. The type-type residuals are computed and then sorted for each replicate, so that for each $i = 1, 2, ..., n$, where n is the number of individuals in the sample, there is a random sample of size rep of the i-th order statistic of the type-type residuals. Therefore, the simulated envelope is composed of the quantiles (1 - conf)/2 and (1 + conf)/2 of the random sample of size rep of the i-th order statistic of the type-type residuals for $i = 1, 2, ..., n$.

Value

A matrix with the following four columns:

Lower limit	the quantile (1 - conf)/2 of the random sample of size rep of the i-th order statistic of the type-type residuals for $i = 1, 2, ..., n$,
Median	the quantile 0.5 of the random sample of size rep of the i-th order statistic of the type-type residuals for $i = 1, 2, ..., n$,

`Upper limit` the quantile (1 + `conf`)/2 of the random sample of size `rep` of the i-th order statistic of the `type`-type residuals for $i = 1, 2, ..., n$,

`Residuals` the observed `type`-type residuals,

References

Atkinson, A.C. (1985) *Plots, Transformations and Regression*. Oxford University Press, Oxford.

Davison, A.C. and Gigli, A. (1989) Deviance Residuals and Normal Scores Plots. *Biometrika* 76, 211-221.

Dunn, P.K. and Smyth, G.K. (1996) Randomized Quantile Residuals. *Journal of Computational and Graphical Statistics* 5, 236-244.

Pierce, D.A. and Schafer, D.W. (1986) Residuals in Generalized Linear Models. *Journal of the American Statistical Association* 81, 977-986.

See Also

envelope.lm, envelope.overglm

Examples

```
###### Example 1:
burn1000 <- aplore3::burn1000
burn1000 <- within(burn1000, death <- factor(death, levels=c("Dead","Alive")))
fit1 <- glm(death ~ age*inh_inj + tbsa*inh_inj, family=binomial("logit"), data=burn1000)
envelope(fit1, rep=50, conf=0.95, type="pearson", col="red", pch=20, col.lab="blue",
         col.axis="blue", col.main="black", family="mono", cex=0.8)

###### Example 2: Fuel consumption of automobiles
Auto <- ISLR::Auto
fit2 <- glm(mpg ~ horsepower*weight, family=inverse.gaussian("log"), data=Auto)
envelope(fit2, rep=50, conf=0.95, type="pearson", col="red", pch=20, col.lab="blue",
         col.axis="blue", col.main="black", family="mono", cex=0.8)

###### Example 3: Skin cancer in women
fit3 <- glm(cases ~ offset(log(population)) + city + age, family=poisson, data=skincancer)
envelope(fit3, rep=100, conf=0.95, type="quantile", col="red", pch=20,col.lab="blue",
         col.axis="blue",col.main="black",family="mono",cex=0.8)

###### Example 4: Self diagnozed ear infections in swimmers
fit4 <- glm(infections ~ frequency + location, family=poisson(log), data=swimmers)
envelope(fit4, rep=100, conf=0.95, type="quantile", col="red", pch=20, col.lab="blue",
         col.axis="blue", col.main="black", family="mono", cex=0.8)

###### Example 5: Agents to stimulate cellular differentiation
fit5 <- glm(cbind(cells,200-cells) ~ tnf + ifn, family=binomial(logit), data=cellular)
envelope(fit5, rep=100, conf=0.95, type="quantile", col="red", pch=20, col.lab="blue",
```

```
col.axis="blue", col.main="black", family="mono", cex=0.8)
```

`envelope.lm` *Normal QQ-plot with simulated envelope of residuals for normal linear models*

Description

Produces a normal QQ-plot with simulated envelope of residuals obtained from the fit of a normal linear model.

Usage

```
## S3 method for class 'lm'
envelope(
  object,
  rep = 100,
  conf = 0.95,
  type = c("external", "internal"),
  plot.it = TRUE,
  identify,
  ...
)
```

Arguments

`object`	an object of the class *lm*.
`rep`	an (optional) positive integer indicating the number of replicates which should be used to build the simulated envelope. By default, `rep` is set to be 100.
`conf`	an (optional) value in the interval (0,1) indicating the confidence level which should be used to build the pointwise confidence intervals, which form the envelope. By default, `conf` is set to be 0.95.
`type`	a character string indicating the type of residuals which should be used. The available options are: internally Studentized ("internal") and externally Studentized ("external") residuals. See Cook and Weisberg (1982, pages 18-20).
`plot.it`	an (optional) logical switch indicating if the normal QQ-plot with simulated envelope of residuals is required or just the data matrix in which it is based. By default, `plot.it` is set to be TRUE.
`identify`	an (optional) positive integer value indicating the number of individuals to identify on the QQ-plot with simulated envelope of residuals. This is only appropriate if `plot.it=TRUE`.
`...`	further arguments passed to or from other methods. If `plot.it=TRUE` then `...` may be used to include graphical parameters to customize the plot. For example, `col`, `pch`, `cex`, `main`, `sub`, `xlab`, `ylab`.

Details

The simulated envelope is builded by simulating rep independent realizations of the response variable for each individual, which is accomplished taking into account the following: (1) the model assumption about the distribution of the response variable; (2) the estimates of the parameters in the linear predictor; and (3) the estimate of the dispersion parameter. The interest model is re-fitted rep times, as each time the vector of observed responses is replaced by one of the simulated samples. The type-type residuals are computed and then sorted for each replicate, so that for each $i = 1, 2, ..., n$, where n is the number of individuals in the sample, there is a random sample of size rep of the i-th order statistic of the type-type residuals. Therefore, the simulated envelope is composed of the quantiles (1 - conf)/2 and (1 + conf)/2 of the random sample of size rep of the i-th order statistic of the type-type residuals for $i = 1, 2, ..., n$.

Value

A matrix with the following four columns:

Lower limit	the quantile (1 - conf)/2 of the random sample of size rep of the i-th order statistic of the type-type residuals for $i = 1, 2, ..., n$,
Median	the quantile 0.5 of the random sample of size rep of the i-th order statistic of the type-type residuals for $i = 1, 2, ..., n$,
Upper limit	the quantile (1 + conf)/2 of the random sample of size rep of the i-th order statistic of the type-type residuals for $i = 1, 2, ..., n$,
Residuals	the observed type-type residuals,

References

Atkinson, A.C. (1985) *Plots, Transformations and Regression*. Oxford University Press, Oxford.

Cook, R.D. and Weisberg, S. (1982) *Residuals and Influence in Regression*. Chapman and Hall, New York.

See Also

envelope.glm, envelope.overglm

Examples

```
###### Example 1: Fuel consumption of automobiles
fit1 <- lm(mpg ~ log(hp) + log(wt), data=mtcars)
envelope(fit1, rep=100, conf=0.95, type="external", col="red", pch=20, col.lab="blue",
         col.axis="blue", col.main="black", family="mono", cex=0.8)

###### Example 2: Species richness in plots
fit2 <- lm(Species ~ Biomass + pH + Biomass*pH, data=richness)
envelope(fit2, rep=100, conf=0.95, type="internal", col="red", pch=20, col.lab="blue",
         col.axis="blue", col.main="black", family="mono", cex=0.8)
```

```
###### Example 3: Gas consumption in a home before and after insulation
whiteside <- MASS::whiteside
fit3 <- lm(Gas ~ Temp + Insul + Temp*Insul, data=whiteside)
envelope(fit3, rep=100, conf=0.95, type="internal", col="red", pch=20, col.lab="blue",
         col.axis="blue", col.main="black", family="mono", cex=0.8)
```

`envelope.overglm` *Normal QQ-plot with Simulated Envelope of Residuals for alternatives to the Poisson and Binomial Regression Models under the presence of Overdispersion*

Description

Produces a normal QQ-plot with simulated envelope of residuals for regression models based on the negative binomial, beta-binomial, and random-clumped binomial distributions, which are alternatives to the Poisson and binomial regression models under the presence of overdispersion.

Usage

```
## S3 method for class 'overglm'
envelope(
  object,
  rep = 25,
  conf = 0.95,
  type = c("quantile", "response", "standardized"),
  plot.it = FALSE,
  identify,
  ...
)
```

Arguments

`object`	an object of class *overglm*.
`rep`	an (optional) positive integer which allows to specify the number of replicates which should be used to build the simulated envelope. By default, `rep` is set to be 25.
`conf`	an (optional) value in the interval $(0, 1)$ indicating the confidence level which should be used to build the pointwise confidence intervals, which conform the simulated envelope. By default, `conf` is set to be 0.95.
`type`	an (optional) character string which allows to specify the required type of residuals. The available options are: (1) the difference between the observed response and the fitted mean ("response"); (2) the standardized difference between the observed response and the fitted mean ("standardized"); and (3) the randomized quantile residual ("quantile"). By default, `type` is set to be "quantile".

`plot.it`	an (optional) logical switch indicating if the normal QQ-plot with simulated envelope of residuals is required or just the data matrix in which it is based. By default, `plot.it` is set to be TRUE.
`identify`	an (optional) positive integer value indicating the number of individuals to identify on the QQ-plot with simulated envelope of residuals. This is only appropriate if `plot.it=TRUE`.
`...`	further arguments passed to or from other methods. If `plot.it=TRUE` then `...` may be used to include graphical parameters to customize the plot. For example, `col`, `pch`, `cex`, `main`, `sub`, `xlab`, `ylab`.

Details

The simulated envelope is builded by simulating `rep` independent realizations of the response variable for each individual, which is accomplished taking into account the following: (1) the model assumption about the distribution of the response variable; (2) the estimates of the parameters in the linear predictor; and (3) the estimate of the dispersion parameter. The interest model is re-fitted `rep` times, as each time the vector of observed responses is replaced by one of the simulated samples. The `type`-type residuals are computed and then sorted for each replicate, so that for each $i = 1, 2, ..., n$, where n is the number of individuals in the sample, there is a random sample of size `rep` of the i-th order statistic of the `type`-type residuals. Therefore, the simulated envelope is composed of the quantiles (1 - `conf`)/2 and (1 + `conf`)/2 of the random sample of size `rep` of the i-th order statistic of the `type`-type residuals for $i = 1, 2, ..., n$.

Value

A matrix with the following four columns:

`Lower limit`	the quantile (1 - `conf`)/2 of the random sample of size `rep` of the i-th order statistic of the `type`-type residuals for $i = 1, 2, ..., n$,
`Median`	the quantile 0.5 of the random sample of size `rep` of the i-th order statistic of the `type`-type residuals for $i = 1, 2, ..., n$,
`Upper limit`	the quantile (1 + `conf`)/2 of the random sample of size `rep` of the i-th order statistic of the `type`-type residuals for $i = 1, 2, ..., n$,
`Residuals`	the observed `type`-type residuals,

References

Atkinson A.C. (1985) *Plots, Transformations and Regression*. Oxford University Press, Oxford.

Dunn P.K. and Smyth G.K. (1996) Randomized Quantile Residuals. *Journal of Computational and Graphical Statistics* 5, 236-244.

See Also

envelope.lm, envelope.glm, envelope.zeroinflation

Examples

```
###### Example 1: Self diagnozed ear infections in swimmers
fit1 <- overglm(infections ~ frequency + location, family="nb1(log)", data=swimmers)
envelope(fit1, rep=30, conf=0.95, type="quantile", col="red", pch=20, col.lab="blue",
         col.axis="blue", col.main="black", family="mono", cex=0.8, plot.it=TRUE)

###### Example 2: Article production by graduate students in biochemistry PhD programs
bioChemists <- pscl::bioChemists
fit2 <- overglm(art ~ fem + kid5 + ment, family="nb1(log)", data = bioChemists)
envelope(fit2, rep=30, conf=0.95, type="quantile", col="red", pch=20, col.lab="blue",
         col.axis="blue", col.main="black", family="mono", cex=0.8, plot.it=TRUE)

###### Example 3: Agents to stimulate cellular differentiation
fit3 <- overglm(cbind(cells,200-cells) ~ tnf + ifn, family="bb(logit)", data=cellular)
envelope(fit3, rep=30, conf=0.95, type="quantile", col="red", pch=20, col.lab="blue",
         col.axis="blue", col.main="black", family="mono", cex=0.8, plot.it=TRUE)
```

`envelope.zeroinflation`

Normal QQ-plot with Simulated Envelope of Residuals for Regression Models to deal with Zero-Excess in Count Data

---

Description

Produces a normal QQ-plot with simulated envelope of residuals for regression models used to deal with zero-excess in count data.

Usage

```
## S3 method for class 'zeroinflation'
envelope(
  object,
  rep = 20,
  conf = 0.95,
  type = c("quantile", "response", "standardized"),
  plot.it = FALSE,
  identify,
  ...
)
```

Arguments

`object`	an object of the class *zeroinflation*.
`rep`	an (optional) positive integer which allows to specify the number of replicates which should be used to build the simulated envelope. By default, `rep` is set to be 25.

conf	an (optional) value in the interval $(0, 1)$ indicating the confidence level which should be used to build the pointwise confidence intervals, which conform the simulated envelope. By default, conf is set to be 0.95.
type	an (optional) character string which allows to specify the required type of residuals. The available options are: (1) the difference between the observed response and the fitted mean ("response"); (2) the standardized difference between the observed response and the fitted mean ("standardized"); (3) the randomized quantile residual ("quantile"). By default, type is set to be "quantile".
plot.it	an (optional) logical switch indicating if the normal QQ-plot with simulated envelope of residuals is required or just the data matrix in which it is based. By default, plot.it is set to be TRUE.
identify	an (optional) positive integer value indicating the number of individuals to identify on the QQ-plot with simulated envelope of residuals. This is only appropriate if plot.it=TRUE.
...	further arguments passed to or from other methods. If plot.it=TRUE then ... may be used to include graphical parameters to customize the plot. For example, col, pch, cex, main, sub, xlab, ylab.

Details

The simulated envelope is builded by simulating rep independent realizations of the response variable for each individual, which is accomplished taking into account the following: (1) the model assumption about the distribution of the response variable; (2) the estimates of the parameters in the linear predictor; and (3) the estimate of the dispersion parameter. The interest model is re-fitted rep times, as each time the vector of observed responses is replaced by one of the simulated samples. The type-type residuals are computed and then sorted for each replicate, so that for each $i = 1, 2, ..., n$, where n is the number of individuals in the sample, there is a random sample of size rep of the i-th order statistic of the type-type residuals. Therefore, the simulated envelope is composed of the quantiles (1 - conf)/2 and (1 + conf)/2 of the random sample of size rep of the i-th order statistic of the type-type residuals for $i = 1, 2, ..., n$.

Value

A matrix with the following four columns:

Lower limit	the quantile (1 - conf)/2 of the random sample of size rep of the i-th order statistic of the type-type residuals for $i = 1, 2, ..., n$,
Median	the quantile 0.5 of the random sample of size rep of the i-th order statistic of the type-type residuals for $i = 1, 2, ..., n$,
Upper limit	the quantile (1 + conf)/2 of the random sample of size rep of the i-th order statistic of the type-type residuals for $i = 1, 2, ..., n$,
Residuals	the observed type-type residuals,

References

Atkinson A.C. (1985) *Plots, Transformations and Regression*. Oxford University Press, Oxford.

Dunn P.K. and Smyth G.K. (1996) Randomized Quantile Residuals. *Journal of Computational and Graphical Statistics* 5, 236-244.

See Also

envelope.lm, envelope.glm, envelope.overglm

Examples

```
####### Example 1: Self diagnozed ear infections in swimmers
fit <- zeroinf(infections ~ frequency | location, family="nb1(log)", data=swimmers)
envelope(fit, rep=30, conf=0.95, type="quantile", col="red", pch=20, col.lab="blue",
         col.axis="blue", col.main="black", family="mono", cex=0.8)
```

`estequa` *Function to extract estimating equations*

Description

Extracts estimating equations evaluated at the parameter estimates and the observed data for a fitted model object.

Usage

```
estequa(object, ...)
```

Arguments

`object`	a fitted model object.
`...`	further arguments passed to or from other methods.

Value

A vector with the value of the estimating equations evaluated at the parameter estimates and the observed data.

estequa.glm *Estimating Equations in Generalized Linear Models*

Description

Extracts estimating equations evaluated at the parameter estimates and the observed data for a generalized linear model fitted to the data.

Usage

```
## S3 method for class 'glm'
estequa(object, ...)
```

Arguments

object	an object of the class glm which is obtained from the fit of a generalized linear model.
...	further arguments passed to or from other methods.

Value

A vector with the value of the estimating equations evaluated at the parameter estimates and the observed data.

Examples

```
## Example 1
Auto <- ISLR::Auto
mod <- mpg ~ cylinders + displacement + acceleration + origin + horsepower*weight
fit1 <- glm(mod, family=inverse.gaussian("log"), data=Auto)
estequa(fit1)

## Example 2
burn1000 <- aplore3::burn1000
burn1000 <- within(burn1000, death <- factor(death, levels=c("Dead","Alive")))
mod2 <- death ~ age + gender + race + tbsa + inh_inj + flame + age*inh_inj + tbsa*inh_inj
fit2 <- glm(mod2, family=binomial("logit"), data=burn1000)
estequa(fit2)

## Example 3
fit3 <- glm(cases ~ offset(log(population)) + city + age, family=poisson("log"), data=skincancer)
estequa(fit3)
```

estequa.glmgee *Estimating Equations in Generalized Estimating Equations*

Description

Extracts estimating equations evaluated at the parameter estimates and the observed data for a generalized estimating equation fitted to the data.

Usage

```
## S3 method for class 'glmgee'
estequa(object, ...)
```

Arguments

object	an object of class *glmgee*.
...	further arguments passed to or from other methods.

Value

A vector with the value of the estimating equations evaluated at the parameter estimates and the observed data.

Examples

```
###### Example 1: Effect of ozone-enriched atmosphere on growth of sitka spruces
mod1 <- size ~ poly(days,4) + treat
fit1 <- glmgee(mod1, id=tree, family=Gamma("log"), corstr="AR-1", data=spruces)
estequa(fit1)

###### Example 2: Treatment for severe postnatal depression
mod2 <- depressd ~ visit + group
fit2 <- glmgee(mod2, id=subj, family=binomial("logit"), corstr="AR-1", data=depression)
estequa(fit2)

###### Example 3: Treatment for severe postnatal depression (2)
mod3 <- dep ~ visit*group
fit3 <- glmgee(mod3, id=subj, family=gaussian("identity"), corstr="AR-1", data=depression)
estequa(fit3)

###### Example 4: Dental Clinical Trial
mod4 <- score/3.6 ~ rinse*time
fit4 <- glmgee(mod4, family=binomial(log), id=subject, corstr="Exchangeable", data=rinse)
estequa(fit4)

###### Example 5: Shoulder Pain after Laparoscopic Cholecystectomy
mod5 <- pain2 ~ treatment + age + time
corstr <- "Stationary-M-dependent(2)"
fit5 <- glmgee(mod5, family=binomial(logit), id=id, corstr=corstr, data=cholecystectomy)
```

```
estequa(fit5)

###### Example 6: Guidelines for Urinary Incontinence Discussion and Evaluation
mod6 <- bothered ~ gender + age + dayacc + severe + toilet
fit6 <- glmgee(mod6, family=binomial(logit), id=practice, corstr="Exchangeable", data=GUIDE)
estequa(fit6)

###### Example 7: Tests of Auditory Perception in Children with OME
OME <- MASS::OME
mod7 <- cbind(Correct, Trials-Correct) ~ Loud + Age + OME
fit7 <- glmgee(mod7, family = binomial(cloglog), id = ID, corstr = "Exchangeable", data = OME)
estequa(fit7)
```

`estequa.overglm` *Estimating Equations for alternatives to the Poisson and Binomial Regression Models under the presence of Overdispersion.*

Description

Computes the estimating equations evaluated at the parameter estimates and the observed data for regression models based on the negative binomial, beta-binomial, and random-clumped binomial distributions, which are alternatives to the Poisson and binomial regression models under the presence of overdispersion.

Usage

```
## S3 method for class 'overglm'
estequa(object, ...)
```

Arguments

`object`	an object of the class *overglm*.
`...`	further arguments passed to or from other methods.

Value

A vector with the values of the estimating equations evaluated at the parameter estimates and the observed data.

Examples

```
### Example 1: Ability of retinyl acetate to prevent mammary cancer in rats
fit1 <- overglm(tumors ~ group, family="nb1(identity)", data=mammary)
estequa(fit1)

### Example 2: Self diagnozed ear infections in swimmers
fit2 <- overglm(infections ~ frequency + location, family="nb1(log)", data=swimmers)
estequa(fit2)
```

```
### Example 3: Urinary tract infections in HIV-infected men
fit3 <- overglm(episodes ~ cd4 + offset(log(time)), family="nb1(log)", data = uti)
estequa(fit3)

### Example 4: Article production by graduate students in biochemistry PhD programs
bioChemists <- pscl::bioChemists
fit4 <- overglm(art ~ fem + kid5 + ment, family="nb1(log)", data = bioChemists)
estequa(fit4)

### Example 5: Agents to stimulate cellular differentiation
fit5 <- overglm(cbind(cells,200-cells) ~ tnf + ifn, family="bb(logit)", data=cellular)
estequa(fit5)

### Example 6: Teratogenic effects of phenytoin and trichloropropene oxide
model6 <- cbind(fetuses,litter-fetuses) ~ pht + tcpo
fit6 <- overglm(model6, family="rcb(cloglog)", data=ossification)
estequa(fit6)

### Example 7: Germination of orobanche seeds
model7 <- cbind(germinated,seeds-germinated) ~ specie + extract
fit7 <- overglm(model7, family="rcb(cloglog)", data=orobanche)
estequa(fit7)
```

`estequa.zeroinflation` *Estimating Equations in Regression Models to deal with Zero-Excess in Count Data*

Description

Computes the estimating equations evaluated at the parameter estimates and the observed data for regression models to deal with zero-excess in count data.

Usage

```
## S3 method for class 'zeroinflation'
estequa(object, submodel = c("counts", "zeros"), ...)
```

Arguments

`object`	an object of the class *zeroinflation*.
`submodel`	an (optional) character string which allows to specify the model: "counts" or "zeros". By default, `submodel` is set to be "counts".
`...`	further arguments passed to or from other methods.

Value

A vector with the values of the estimating equations evaluated at the parameter estimates and the observed data.

Examples

```
####### Example 1: Roots Produced by the Columnar Apple Cultivar Trajan
fit1 <- zeroalt(roots ~ photoperiod, family="nbf(log)", zero.link="logit", data=Trajan)
estequa(fit1)

fit1a <- zeroinf(roots ~ photoperiod, family="nbf(log)", zero.link="logit", data=Trajan)
estequa(fit1a)

####### Example 2: Self diagnozed ear infections in swimmers
fit2 <- zeroalt(infections ~ frequency | location, family="nb1(log)", data=swimmers)
estequa(fit2)

fit2a <- zeroinf(infections ~ frequency | location, family="nb1(log)", data=swimmers)
estequa(fit2a)

####### Example 3: Article production by graduate students in biochemistry PhD programs
bioChemists <- pscl::bioChemists
fit3 <- zeroalt(art ~ fem + kid5 + ment, family="nb1(log)", data = bioChemists)
estequa(fit3)

fit3a <- zeroinf(art ~ fem + kid5 + ment | ment, family="nb1(log)", data = bioChemists)
estequa(fit3a)
```

GHYC *Gosho-Hamada-Yoshimura's Criterion for Generalized Estimating Equations*

Description

Computes the Gosho-Hamada-Yoshimura's criterion (GHYC) for one or more objects of the class glmgee.

Usage

```
GHYC(..., verbose = TRUE)
```

Arguments

`...`	one or several objects of the class *glmgee*.
`verbose`	an (optional) logical switch indicating if should the report of results be printed. By default, `verbose` is set to be TRUE.

Value

A `data.frame` with the values of the GHYC for each *glmgee* object in the input.

References

Gosho, M. and Hamada, C. and Yoshimura, I. (2011) Criterion for the Selection of a Working Correlation Structure in the Generalized Estimating Equation Approach for Longitudinal Balanced Data. *Communications in Statistics — Theory and Methods* 40, 3839-3856.

Gosho, M. (2014) Criteria to Select a Working Correlation Structure in SAS. *Journal of Statistical Software, Code Snippets* 57, 1548-7660.

See Also

QIC, CIC, RJC, AGPC, SGPC

Examples

```
###### Example 1: Effect of ozone-enriched atmosphere on growth of sitka spruces
mod1 <- size ~ poly(days,4) + treat
fit1 <- glmgee(mod1, id=tree, family=Gamma("log"), data=spruces)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Stationary-M-dependent(2)")
fit4 <- update(fit1, corstr="Exchangeable")
GHYC(fit1, fit2, fit3, fit4)

###### Example 2: Treatment for severe postnatal depression
mod2 <- depressd ~ visit + group
fit1 <- glmgee(mod2, id=subj, family=binomial("logit"), data=depression)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Stationary-M-dependent(2)")
fit4 <- update(fit1, corstr="Exchangeable")
GHYC(fit1, fit2, fit3, fit4)

###### Example 3: Treatment for severe postnatal depression (2)
mod3 <- dep ~ visit*group
fit1 <- glmgee(mod3, id=subj, family=gaussian("identity"), data=depression)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Exchangeable")
GHYC(fit1, fit2, fit3)
```

`glmgee` *Fit Generalized Estimating Equations*

Description

Produces an object of the class `glmgee` in which the main results of a Generalized Estimating Equation (GEE) fitted to the data are stored.

Usage

```
glmgee(
  formula,
  family = gaussian(),
  weights,
  id,
  waves,
  data,
  subset,
  corstr,
  corr,
  start = NULL,
  scale.fix = FALSE,
  scale.value = 1,
  toler = 1e-05,
  maxit = 50,
  adjr2 = FALSE,
  ...
)
```

Arguments

formula	a formula expression of the form response ~ x1 + x2 + ..., which is a symbolic description of the linear predictor of the model to be fitted to the data.
family	an (optional) family object, that is, a list of functions and expressions for defining link and variance functions. Families (and links) supported are the same supported by glm using its family argument, that is, gaussian, binomial, poisson, Gamma, inverse.gaussian, and quasi. The family negative.binomial in the library **MASS** are also available. By default, the argument family is set to be gaussian("identity").
weights	an (optional) vector of positive "prior weights" to be used in the fitting process. The length of weights should be the same as the total number of observations.
id	a vector which identifies the subjects or clusters. The length of id should be the same as the number of observations.
waves	an (optional) positive integer-valued variable that is used to identify the order and spacing of observations within clusters. This argument is crucial when there are missing values and gaps in the data. By default, waves is equal to the integers from 1 to the size of each cluster.
data	an (optional) data frame in which to look for variables involved in the formula expression, as well as for variables specified in the arguments id and weights. The data are assumed to be sorted by id and time.
subset	an (optional) vector specifying a subset of observations to be used in the fitting process.
corstr	an (optional) character string which allows to specify the working-correlation structure. The available options are: "Independence", "Unstructured", "Stationary-M-dependent(*m*)", "Non-Stationary-M-dependent(*m*)", "AR-1", "Exchangeable"

and "User-defined", where *m* represents the lag of the dependence. By default, `corstr` is set to be "Independence".

`corr` an (optional) square matrix of the same dimension of the maximum cluster size containing the user specified correlation. This is only appropriate if `corstr` is specified to be "User-defined".

`start` an (optional) vector of starting values for the parameters in the linear predictor.

`scale.fix` an (optional) logical variable. If TRUE, the scale parameter is fixed at the value of `scale.value`. By default, `scale.fix` is set to be FALSE.

`scale.value` an (optional) numeric value at which the scale parameter should be fixed. This is only appropriate if `scale.fix=TRUE`. By default, `scale.value` is set to be 1.

`toler` an (optional) positive value which represents the *convergence tolerance*. The convergence is reached when the maximum of the absolute relative differences between the values of the parameters in the linear predictor in consecutive iterations of the fitting algorithm is lower than `toler`. By default, `toler` is set to be 0.00001.

`maxit` an (optional) integer value which represents the maximum number of iterations allowed for the fitting algorithm. By default, `maxit` is set to be 50.

`adjr2` an (optional) logical variable. If TRUE, the adjusted R-squared based on the deviance is computed. By default, `adjr2` is set to be FALSE.

`...` further arguments passed to or from other methods.

Details

The values of the multivariate response variable measured on n subjects or clusters, denoted by $y_i = (y_{i1}, \ldots, y_{in_i})^\top$ for $i = 1, \ldots, n$, are assumed to be realizations of independent random vectors denoted by $Y_i = (Y_{i1}, \ldots, Y_{in_i})^\top$ for $i = 1, \ldots, n$. The random variables associated to the i-th subject or cluster, Y_{ij} for $j = 1, \ldots, n_i$, are assumed to satisfy $\mu_{ij} = \mathrm{E}(Y_{ij})$,$\mathrm{Var}(Y_{ij}) = \frac{\phi}{\omega_{ij}}\mathrm{V}(\mu_{ij})$ and $\mathrm{Corr}(Y_{ij}, Y_{ik}) = r_{jk}(\rho)$, where $\phi > 0$ is the dispersion parameter, $\mathrm{V}(\mu_{ij})$ is the variance function, $\omega_{ij} > 0$ is a known weight, and $\rho = (\rho_1, \ldots, \rho_q)^\top$ is a parameter vector. In addition, μ_{ij} is assumed to be dependent on the regressors vector x_{ij} by $g(\mu_{ij}) = z_{ij} + x_{ij}^\top \beta$, where $g(\cdot)$ is the link function, z_{ij} is a known *offset* and $\beta = (\beta_1, \ldots, \beta_p)^\top$ is a vector of regression parameters. The parameter estimates are obtained by iteratively solving the estimating equations described by Liang and Zeger (1986).

If the maximum cluster size is 6 and for a cluster of size 4 the value of `waves` is set to be 2, 4, 5, 6, then it means that the data on times 1 and 3 are missing, which should be taken into account by `glmgee` when the structure of the correlation matrix is assumed to be "Unstructured", "Stationary-M-dependent", "Non-Stationary-M-dependent" or "AR-1". If in this scenario `waves` is not specified then `glmgee` assumes that the available data for this cluster were taken on point times 1, 2, 3 and 4.

A set of standard extractor functions for fitted model objects is available for objects of class *glmgee*, including methods to the generic functions such as `print`, `summary`, `model.matrix`, `estequa`, `coef`, `vcov`, `logLik`, `fitted`, `confint` and `predict`. In addition, the model may be assessed using functions such as anova.glmgee, residuals.glmgee, dfbeta.glmgee, cooks.distance.glmgee and localInfluence.glmgee. The variable selection may be accomplished using the routine stepCriterion.glmgee.

Value

an object of class *glmgee* in which the main results of the GEE model fitted to the data are stored, i.e., a list with components including

`coefficients`	a vector with the estimates of $\beta_1, \ldots, \beta_p$,
`fitted.values`	a vector with the estimates of μ_{ij} for $i = 1, \ldots, n$ and $j = 1, \ldots, n_i$,
`start`	a vector with the starting values used,
`prior.weights`	a vector with the values of ω_{ij} for $i = 1, \ldots, n$ and $j = 1, \ldots, n_i$,
`offset`	a vector with the values of z_{ij} for $i = 1, \ldots, n$ and $j = 1, \ldots, n_i$,
`terms`	an object containing the terms objects,
`loglik`	the value of the quasi-log-likelihood function evaluated at the parameter estimates and the observed data,
`estfun`	a vector with the estimating equations evaluated at the parameter estimates and the observed data,
`formula`	the formula,
`levels`	the levels of the categorical regressors,
`contrasts`	an object containing the contrasts corresponding to levels,
`converged`	a logical indicating successful convergence,
`model`	the full model frame,
`y`	a vector with the values of y_{ij} for $i = 1, \ldots, n$ and $j = 1, \ldots, n_i$,
`family`	an object containing the family object used,
`linear.predictors`	a vector with the estimates of $g(\mu_{ij})$ for $i = 1, \ldots, n$ and $j = 1, \ldots, n_i$,
`R`	a matrix with the (robust) estimate of the variance-covariance,
`corr`	a matrix with the estimate of the working-correlation,
`corstr`	a character string specifying the working-correlation structure,
`id`	a vector which identifies the subjects or clusters,
`sizes`	a vector with the values of n_i for $i = 1, \ldots, n$,

`call` the original function call,

References

Liang, K.Y. and Zeger, S.L. (1986) Longitudinal data analysis using generalized linear models. *Biometrika* 73, 13-22.

Zeger, S.L. and Liang, K.Y. (1986) Longitudinal data analysis for discrete and continuous outcomes. *Biometrics* 42, 121-130.

Hardin, J.W. and Hilbe, J.M. (2013). *Generalized Estimating Equations*. Chapman & Hall, London.

Examples

```
###### Example 1: Effect of ozone-enriched atmosphere on growth of sitka spruces
mod1 <- size ~ poly(days,4) + treat
fit1 <- glmgee(mod1, id=tree, family=Gamma("log"), corstr="AR-1", data=spruces)
summary(fit1, corr.digits=2)

###### Example 2: Treatment for severe postnatal depression
mod2 <- depressd ~ visit + group
fit2 <- glmgee(mod2, id=subj, family=binomial("logit"), corstr="AR-1", data=depression)
summary(fit2, corr.digits=2)

###### Example 3: Treatment for severe postnatal depression (2)
mod3 <- dep ~ visit*group
fit3 <- glmgee(mod3, id=subj, family=gaussian("identity"), corstr="AR-1", data=depression)
summary(fit3, corr.digits=2)

###### Example 4: Dental Clinical Trial
mod4 <- score/3.6 ~ rinse*time
fit4 <- glmgee(mod4, family=binomial("log"), id=subject, corstr="Exchangeable", data=rinse)
summary(fit4, corr.digits=2)

###### Example 5: Shoulder Pain after Laparoscopic Cholecystectomy
mod5 <- pain2 ~ treatment + age + time
corstr <- "Stationary-M-dependent(2)"
fit5 <- glmgee(mod5, family=binomial("logit"), id=id, corstr=corstr, data=cholecystectomy)
summary(fit5,varest="bias-corrected")

###### Example 6: Guidelines for Urinary Incontinence Discussion and Evaluation
mod6 <- bothered ~ gender + age + dayacc + severe + toilet
fit6 <- glmgee(mod6, family=binomial("logit"), id=practice, corstr="Exchangeable", data=GUIDE)
summary(fit6)

###### Example 7: Tests of Auditory Perception in Children with OME
OME <- MASS::OME
mod7 <- cbind(Correct, Trials-Correct) ~ Loud + Age + OME
fit7 <- glmgee(mod7, family = binomial("cloglog"), id = ID, corstr = "Exchangeable", data = OME)
summary(fit7, corr=FALSE)
```

GUIDE *Guidelines for Urinary Incontinence Discussion and Evaluation*

Description

These data arose from a randomized controlled trial that assessed if provider adherence to a set of guidelines for treatment of patients with urinary incontinence (UI) affected patient outcomes. Data were collected on 137 elderly patients from 38 medical practices. The number of patients per practice ranged from 1 to 8 and the median was 4 patients. The interest of the present analysis is to determine what predicts whether or not a patient considers their UI a problem that interferes with him/her daily life.

Usage

```
data(GUIDE)
```

Format

A data frame with 137 rows and 7 variables:

bothered a numeric vector giving the answer to the following: Do you consider this accidental loss of urine a problem that interferes with your day to day activities or bothers you in other ways? 1 for "Yes" and 0 for "No".

gender a factor giving the patient's gender: "Male" or "Female".

age a numeric vector giving the standardized age: (age in years - 76)/10.

dayacc a numeric vector giving the patient's report of the number of leaking accidents they experience in an average day (derived from number of accidents reported per week).

severe a factor giving the severity of the loss of urine: "1" if there is only some moisture; "2" if the patient wet the underwear; "3" if the urine trickled down the thigh; and "4" if the patient wet the floor.

toilet a numeric vector giving the patient's report on the number of times during the day he (or she) usually go to the toilet to urinate.

practice a character string giving the identifier of the medical practice.

Source

http://www.bios.unc.edu/~preisser/personal/uidata/preqaq99.dat

References

Hammill, B.G. and Preisser, J.S. (2006) A SAS/IML software program for GEE and regression diagnostics. *Computational Statistics & Data Analysis* 51, 1197-1212.

Jung, K.-M. (2008) Local Influence in Generalized Estimating Equations. *Scandinavian Journal of Statistics* 35, 286-294.

Examples

```
mod <- bothered ~ gender + age + dayacc + severe + toilet
fit <- glmgee(mod, family=binomial(logit), id=practice, corstr="Exchangeable", data=GUIDE)
summary(fit)
```

`gvif` *Generalized Variance Inflation Factor*

Description

Computes the generalized variance inflation factor (GVIF) for a fitted model object.

Usage

```
gvif(model, ...)
```

Arguments

`model`	a fitted model object.
`...`	further arguments passed to or from other methods.

Value

An object with the values of the GVIF for all effects in the model.

`gvif.glm` *Generalized Variance Inflation Factor*

Description

Computes the generalized variance inflation factor (GVIF) for a generalized linear model.

Usage

```
## S3 method for class 'glm'
gvif(model, verbose = TRUE, ...)
```

Arguments

`model`	an object of the class *glm*.
`verbose`	an (optional) logical switch indicating if should the report of results be printed. By default, `verbose` is set to be TRUE.
`...`	further arguments passed to or from other methods.

Details

If the number of degrees of freedom is 1 then the GVIF reduces to the Variance Inflation Factor (VIF).

Value

A matrix with so many rows as effects in the model and the following columns:

`GVIF`	the values of GVIF,
`df`	the number of degrees of freedom,
`GVIF^(1/(2*df))`	the values of $\text{GVIF}^{1/2df}$,

References

Fox, J. and Monette, G. (1992) Generalized collinearity diagnostics, *JASA* 87, 178–183.

See Also

gvif.lm

Examples

```
###### Example 1: Fuel consumption of automobiles
Auto <- ISLR::Auto
Auto2 <- within(Auto, origin <- factor(origin))
mod <- mpg ~ cylinders + displacement + acceleration + origin + horsepower*weight
fit1 <- glm(mod, family=inverse.gaussian("log"), data=Auto2)
gvif(fit1)

###### Example 2: Patients with burn injuries
burn1000 <- aplore3::burn1000
burn1000 <- within(burn1000, death <- factor(death, levels=c("Dead","Alive")))
mod2 <- death ~ gender + race + flame + age*inh_inj + tbsa*inh_inj
fit2 <- glm(mod2, family=binomial("logit"), data=burn1000)
gvif(fit2)

###### Example 3: Hill races in Scotland
fit3 <- glm(rtime ~ log(distance) + log(cclimb), family=Gamma("log"), data=races)
gvif(fit3)
```

`gvif.lm` *Generalized Variance Inflation Factor*

Description

Computes the generalized variance inflation factor (GVIF) for a weighted or unweighted normal linear model.

Usage

```
## S3 method for class 'lm'
gvif(model, verbose = TRUE, ...)
```

Arguments

`model`	an object of the class *lm*.
`verbose`	an (optional) logical switch indicating if should the report of results be printed. By default, `verbose` is set to be TRUE.
`...`	further arguments passed to or from other methods.

Details

If the number of degrees of freedom is 1 then the GVIF reduces to the Variance Inflation Factor (VIF).

Value

A matrix with so many rows as effects in the model and the following columns:

`GVIF`	the values of GVIF,
`df`	the number of degrees of freedom,
`GVIF^(1/(2*df))`	the values of $\text{GVIF}^{1/2df}$,

References

Fox, J. and Monette, G. (1992) Generalized collinearity diagnostics, *JASA* 87, 178–183.

See Also

gvif.glm

Examples

```
###### Example 1: New York air quality measurements
fit1 <- lm(log(Ozone) ~ Solar.R + Temp + Wind, data=airquality)
gvif(fit1)

###### Example 2: Fuel consumption of automobiles
fit2 <- lm(mpg ~ log(hp) + log(wt) + qsec, data=mtcars)
gvif(fit2)
```

```
###### Example 3: Credit card balance
Credit <- ISLR::Credit
fit3 <- lm(Balance ~ Cards + Age + Rating + Income + Student + Limit, data=Credit)
gvif(fit3)
```

`gvif.overglm` *Generalized Variance Inflation Factor for alternatives to the Poisson and Binomial Regression Models under the presence of Overdispersion*

Description

Computes the generalized variance inflation factor (GVIF) for regression models based on the negative binomial, beta-binomial, and random-clumped binomial distributions, which are alternatives to the Poisson and binomial regression models under the presence of overdispersion. The GVIF is aimed to identify collinearity problems.

Usage

```
## S3 method for class 'overglm'
gvif(model, verbose = TRUE, ...)
```

Arguments

`model`	an object of class *overglm*.
`verbose`	an (optional) logical switch indicating if should the report of results be printed. By default, `verbose` is set to be TRUE.
`...`	further arguments passed to or from other methods.

Details

If the number of degrees of freedom is 1 then the GVIF reduces to the Variance Inflation Factor (VIF).

Value

A matrix with so many rows as effects in the model and the following columns:

`GVIF`	the values of GVIF,
`df`	the number of degrees of freedom,
`GVIF^(1/(2*df))`	the values of $\text{GVIF}^{1/2df}$,

References

Fox J. and Monette G. (1992) Generalized collinearity diagnostics, *JASA* 87, 178–183.

See Also

gvif.lm, gvif.glm

Examples

```
###### Example 1: Self diagnozed ear infections in swimmers
fit1 <- overglm(infections ~ frequency + location, family="nb1(log)", data=swimmers)
gvif(fit1)

###### Example 2: Article production by graduate students in biochemistry PhD programs
bioChemists <- pscl::bioChemists
fit2 <- overglm(art ~ fem + kid5 + ment, family="nb1(log)", data = bioChemists)
gvif(fit2)

###### Example 3: Agents to stimulate cellular differentiation
fit3 <- overglm(cbind(cells,200-cells) ~ tnf + ifn, family="bb(logit)", data=cellular)
gvif(fit3)
```

---

hltest *The Hosmer-Lemeshow Goodness-of-Fit Test*

Description

Computes the Hosmer-Lemeshow goodness-of-fit test for a generalized linear model fitted to binary responses.

Usage

```
hltest(model, verbose = TRUE, ...)
```

Arguments

`model`	an object of the class *glm*, which is obtained from the fit of a generalized linear model where the distribution for the response variable is assumed to be binomial.
`verbose`	an (optional) logical switch indicating if should the report of results be printed. By default, `verbose` is set to be TRUE.
`...`	further arguments passed to or from other methods.

Value

A matrix with the following four columns:

`hm`	a matrix with the values of Group, Size, Observed and Expected, which are required to compute the statistic of t
`statistic`	the value of the statistic of the test,
`df`	the number of degrees of freedom, given by the number of groups minus 2,
`p.value`	the *p*-value of the test computed using the Chi-square distribution,

References

Hosmer, D.W. and Lemeshow, S. (2000) *Applied Logistic Regression. 2nd ed.* John Wiley & Sons, New York.

Examples

```
###### Example 1: Patients with burn injuries
burn1000 <- aplore3::burn1000
burn1000 <- within(burn1000, death <- factor(death, levels=c("Dead","Alive")))
fit1 <- glm(death ~ age*inh_inj + tbsa*inh_inj, family=binomial("logit"), data=burn1000)
hltest(fit1)

###### Example 2: Bladder cancer in mice
fit2 <- glm(cancer/exposed ~ dose, weights=exposed, family=binomial("cloglog"), data=bladder)
hltest(fit2)

###### Example 3: Liver cancer in mice
fit3 <- glm(cancer/exposed ~ dose, weights=exposed, family=binomial("probit"), data=liver)
hltest(fit3)
```

`leverage` *Leverage*

Description

Computes leverage measures for a fitted model object.

Usage

```
leverage(object, ...)
```

Arguments

object	a fitted model object.
...	further arguments passed to or from other methods.

Value

An object with the values of the leverage measures.

---

leverage.glmgee *Leverage for Generalized Estimating Equations*

Description

Computes and, optionally, displays a graph of the leverage measures at the cluster- and observation-level.

Usage

```
## S3 method for class 'glmgee'
leverage(
  object,
  level = c("clusters", "observations"),
  plot.it = FALSE,
  identify,
  ...
)
```

Arguments

object	an object of class *glmgee*.
level	an (optional) character string indicating the level for which the leverage measures are required. The options are: cluster-level ("clusters") and observation-level ("observations"). By default, level is set to be "clusters".
plot.it	an (optional) logical indicating if the plot of the measures of leverage are required or just the data matrix in which that plot is based. By default, plot.it is set to be FALSE.
identify	an (optional) integer indicating the number of (level=``clusters'') or observations (level=``observations'') to identify on the plot of the leverage measures. This is only appropriate if plot.it is specified to be TRUE.
...	further arguments passed to or from other methods. If plot.it is specified to be TRUE then ... may be used to include graphical parameters to customize the plot. For example, col, pch, cex, main, sub, xlab, ylab.

Value

A vector with the values of the leverage measures with so many rows as clusters (level=``clusters'') or observations (level=``observations'') in the sample.

References

Preisser, J.S. and Qaqish, B.F. (1996). Deletion diagnostics for generalised estimating equations. *Biometrika*, 83, 551-562.

Hammill, B.G. and Preisser, J.S. (2006). A SAS/IML software program for GEE and regression diagnostics. *Computational Statistics & Data Analysis*, 51, 1197-1212.

Examples

```
###### Example 1: Tests of Auditory Perception in Children with OME
OME <- MASS::OME
mod <- cbind(Correct, Trials-Correct) ~ Loud + Age + OME
fit1 <- glmgee(mod, family = binomial(cloglog), id = ID, corstr = "Exchangeable", data = OME)
leverage(fit1,level="clusters",plot.it=TRUE)

###### Example 2: Guidelines for Urinary Incontinence Discussion and Evaluation
mod <- bothered ~ gender + age + dayacc + severe + toilet
fit2 <- glmgee(mod, family=binomial(logit), id=practice, corstr="Exchangeable", data=GUIDE)
leverage(fit2,level="clusters",plot.it=TRUE)
leverage(fit2,level="observations",plot.it=TRUE)
```

`liver` *Liver cancer in mice*

Description

Female mice were continuously fed dietary concentrations of 2-Acetylaminofluorene (2-AAF), a carcinogenic and mutagenic derivative of fluorene. Serially sacrificed, dead or moribund mice were examined for tumors and dates of deaths were recorded. These data consist of the incidences of liver neoplasms in the mice observed during 18 months.

Usage

```
data(liver)
```

Format

A data frame with 8 rows and 3 variables:

dose a numeric vector giving the dose, in parts per 10^4, of 2-AAF.

exposed a numeric vector giving the number of mice exposed to each dose of 2-AAF.

cancer a numeric vector giving the number of mice with liver cancer for each dose of 2-AAF.

References

Zhang, H. and Zelterman, D. (1999) Binary Regression for Risks in Excess of Subject-Specific Thresholds. *Biometrics* 55, 1247-1251.

See Also

bladder

Examples

```
barplot(100*cancer/exposed ~ dose, beside=TRUE, data=liver, col="red",
        xlab="Dose of 2-AAF", ylab="% of mice with liver cancer")
```

---

localInfluence *Local Influence*

Description

Computes measures of local influence for a fitted model object.

Usage

```
localInfluence(object, ...)
```

Arguments

object	a fitted model object.
...	further arguments passed to or from other methods.

Value

An object with the measures of local influence.

---

localInfluence.glm *Local Influence for Generalized Linear Models*

Description

Computes some measures and, optionally, display graphs of them to perform influence analysis based on the approaches described in Cook (1986).

Usage

```
## S3 method for class 'glm'
localInfluence(
  object,
  type = c("total", "local"),
  perturbation = c("case-weight", "response", "covariate"),
  covariate,
  coefs,
  plot.it = FALSE,
  identify,
  ...
)
```

Arguments

`object`	an object of class *glm*.
`type`	an (optional) character string indicating the type of approach to study the local influence. The options are: the absolute value of the elements of the eigenvector which corresponds to the maximum absolute eigenvalue ("local"); and the absolute value of the elements of the main diagonal ("total"). By default, `type` is set to be "total".
`perturbation`	an (optional) character string indicating the perturbation scheme to apply. The options are: case weight perturbation of observations ("case-weight"); perturbation of covariates ("covariate"); and perturbation of response ("response"). By default, `perturbation` is set to be "case-weight".
`covariate`	an character string which (partially) match with the names of one of the parameters in the linear predictor. This is only appropriate if `perturbation="covariate"`.
`coefs`	an (optional) character string which (partially) match with the names of some of the parameters in the linear predictor.
`plot.it`	an (optional) logical indicating if the plot of the measures of local influence is required or just the data matrix in which that plot is based. By default, `plot.it` is set to be FALSE.
`identify`	an (optional) integer indicating the number of observations to identify on the plot of the measures of local influence. This is only appropriate if `plot.it=TRUE`.
`...`	further arguments passed to or from other methods. If `plot.it=TRUE` then `...` may be used to include graphical parameters to customize the plot. For example, `col`, `pch`, `cex`, `main`, `sub`, `xlab`, `ylab`.

Value

A matrix as many rows as observations in the sample and one column with the values of the measures of local influence.

References

Cook, D. (1986) Assessment of Local Influence. *Journal of the Royal Statistical Society: Series B (Methodological)* 48, 133-155.

Thomas, W. and Cook, D. (1989) Assessing Influence on Regression Coefficients in Generalized Linear Models. *Biometrika* 76, 741-749.

`localInfluence.glmgee` *Local Influence for Generalized Estimating Equations*

Description

Computes some measures and, optionally, display graphs of them to perform influence analysis based on the approaches described in Cook (1986) and Jung (2008).

Usage

```
## S3 method for class 'glmgee'
localInfluence(
  object,
  type = c("total", "local"),
  perturbation = c("cw-clusters", "cw-observations", "response"),
  coefs,
  plot.it = FALSE,
  identify,
  ...
)
```

Arguments

`object`	an object of class *glmgee*.
`type`	an (optional) character string indicating the type of approach to study the local influence. The options are: the absolute value of the elements of the eigenvector which corresponds to the maximum absolute eigenvalue ("local"); and the absolute value of the elements of the main diagonal ("total"). By default, `type` is set to be "total".
`perturbation`	an (optional) character string indicating the perturbation scheme to apply. The options are: case weight perturbation of clusters ("cw-clusters"); Case weight perturbation of observations ("cw-observations"); and perturbation of response ("response"). By default, `perturbation` is set to be "cw-clusters".
`coefs`	an (optional) character string which (partially) match with the names of some of the parameters in the linear predictor.
`plot.it`	an (optional) logical indicating if the plot of the measures of local influence is required or just the data matrix in which that plot is based. By default, `plot.it` is set to be FALSE.
`identify`	an (optional) integer indicating the number of clusters/observations to identify on the plot of the measures of local influence. This is only appropriate if `plot.it=TRUE`.
`...`	further arguments passed to or from other methods. If `plot.it=TRUE` then `...` may be used to include graphical parameters to customize the plot. For example, `col`, `pch`, `cex`, `main`, `sub`, `xlab`, `ylab`.

Value

A matrix as many rows as clusters/observations in the sample and one column with the values of the measures of local influence.

References

Cook, D. (1986) Assessment of Local Influence. *Journal of the Royal Statistical Society: Series B (Methodological)* 48, 133-155.

Jung, K.-M. (2008) Local Influence in Generalized Estimating Equations. *Scandinavian Journal of Statistics* 35, 286-294.

Examples

```
###### Example 1: Effect of ozone-enriched atmosphere on growth of sitka spruces
mod1 <- size ~ poly(days,4) + treat
fit1 <- glmgee(mod1, id=tree, family=Gamma("log"), corstr="AR-1", data=spruces)
localInfluence(fit1,type="total",perturbation="cw-clusters",coefs="treat",plot.it=TRUE)

###### Example 2: Treatment for severe postnatal depression
mod2 <- depressd ~ visit + group
fit2 <- glmgee(mod2, id=subj, family=binomial("logit"), corstr="AR-1", data=depression)
localInfluence(fit2,type="total",perturbation="cw-clusters",coefs="group",plot.it=TRUE)

###### Example 3: Treatment for severe postnatal depression (2)
mod3 <- dep ~ visit*group
fit3 <- glmgee(mod3, id=subj, family=gaussian("identity"), corstr="AR-1", data=depression)
localInfluence(fit3,type="total",perturbation="cw-clusters",coefs="visit:group",plot.it=TRUE)
```

`localInfluence.overglm`

Local Influence for alternatives to the Poisson and Binomial Regression Models under the presence of Overdispersion

---

Description

Computes local influence measures under the case-weight perturbation scheme for alternatives to the Poisson and Binomial Regression Models under the presence of Overdispersion. Those local influence measures may be chosen to correspond to all parameters in the linear predictor or (via `coefs`) for just some subset of them.

Usage

```
## S3 method for class 'overglm'
localInfluence(
  object,
  type = c("total", "local"),
  coefs,
```

```
  plot.it = FALSE,
  identify,
  ...
)
```

Arguments

object	an object of class *overglm*.
type	an (optional) character string which allows to specify the local influence approach: the absolute value of the elements of the main diagonal of the normal curvature matrix ("total") or the eigenvector which corresponds to the maximum absolute eigenvalue of the normal curvature matrix ("local"). By default, type is set to be "total".
coefs	an (optional) character string which (partially) match with the names of some model parameters.
plot.it	an (optional) logical indicating if the plot is required or just the data matrix in which that plot is based. By default, plot.it is set to be FALSE.
identify	an (optional) integer indicating the number of individuals to identify on the plot. This is only appropriate if plot.it=TRUE.
...	further arguments passed to or from other methods. If plot.it=TRUE then ... may be used to include graphical parameters to customize the plot. For example, col, pch, cex, main, sub, xlab, ylab.

Value

A matrix as many rows as individuals in the sample and one column with the values of the local influence measure.

References

Cook R.D. (1986) Assessment of Local Influence. *Journal of the Royal Statistical Society: Series B (Methodological)* 48, 133-155.

Examples

```
###### Example 1: Self diagnozed ear infections in swimmers
fit1 <- overglm(infections ~ frequency + location, family="nb1(log)", data=swimmers)

### Local influence for all parameters in the linear predictor
localInfluence(fit1, type="local", plot.it=TRUE, col="red", lty=1, lwd=1, col.lab="blue",
               col.axis="blue", col.main="black", family="mono", cex=0.8)

### Local influence for the parameter associated with 'frequency'
localInfluence(fit1, type="local", plot.it=TRUE, col="red", lty=1, lwd=1, col.lab="blue",
            coef="frequency", col.axis="blue", col.main="black", family="mono", cex=0.8)

###### Example 2: Article production by graduate students in biochemistry PhD programs
bioChemists <- pscl::bioChemists
fit2 <- overglm(art ~ fem + kid5 + ment, family="nb1(log)", data = bioChemists)
```

```
### Local influence for all parameters in the linear predictor
localInfluence(fit2, type="local", plot.it=TRUE, col="red", lty=1, lwd=1, col.lab="blue",
               col.axis="blue", col.main="black", family="mono", cex=0.8)

### Local influence for the parameter associated with 'fem'
localInfluence(fit2, type="local", plot.it=TRUE, col="red", lty=1, lwd=1, col.lab="blue",
               coef="fem", col.axis="blue", col.main="black", family="mono", cex=0.8)

###### Example 3: Agents to stimulate cellular differentiation
fit3 <- overglm(cbind(cells,200-cells) ~ tnf + ifn, family="bb(logit)", data=cellular)

### Local influence for all parameters in the linear predictor
localInfluence(fit3, type="local", plot.it=TRUE, col="red", lty=1, lwd=1, col.lab="blue",
               col.axis="blue", col.main="black", family="mono", cex=0.8)

### Local influence for the parameter associated with 'tnf'
localInfluence(fit3, type="local", plot.it=TRUE, col="red", lty=1, lwd=1, col.lab="blue",
               coef="tnf", col.axis="blue", col.main="black", family="mono", cex=0.8)
```

`mammary` *Ability of retinyl acetate to prevent mammary cancer in rats*

Description

A total of 76 female rats were injected with a carcinogen for mammary cancer. Then, all animals were given retinyl acetate (retinoid) to prevent mammary cancer for 60 days. After this phase, the 48 animals that remained tumor-free were randomly assigned to continue the retinoid prophylaxis or control. Rats were then palpated for tumors twice weekly, and observations ended 182 days after the initial carcinogen injections began. The main objective of analysis was to assess the difference in the development of tumors between the treated and control groups. See Morel and Nagaraj (2012, page 63).

Usage

```
data(mammary)
```

Format

A data frame with 48 rows and 2 variables:

group a factor giving the group to which the rat was assigned: "retinoid" or "control".

tumors a numeric vector giving the number of tumors identified on the rat.

References

Lawless, J.F. (1987) Regression Methods for Poisson Process Data. *Journal of the American Statistical Association*, 82, 808-815.

Morel, J.G. and Nagaraj, N.K. (2012) *Overdispersion Models in SAS*. SAS Institute Inc., Cary, North Carolina, USA.

Examples

```
boxplot(tumors ~ group, data=mammary, outline=FALSE, xlab="Group",
        ylab="Number of tumors", col=c("yellow","blue"))
```

---

orobanche *Germination of Orobanche Seeds*

Description

These data arose from a study of the germination of two species of Orobanche seeds (O. aegyptiaca 75 and O. aegyptiaca 73) grown on 1/125 dilutions of two different root extract media (cucumber and bean) in a 2×2 factorial layout with replicates. The data consist of the number of seeds and the number germinating for each replicate. Interest focusses on the possible differences in germination rates for the two types of seed and root extract and whether there is any interaction. See Crowder (1978), Hinde and Demetrio (1998).

Usage

```
data(orobanche)
```

Format

A data frame with 21 rows and 4 variables:

specie a factor indicating the specie of Orobanche seed: O. aegyptiaca 75 ("Aegyptiaca 75") and O. aegyptiaca 73 ("Aegyptiaca 73").

extract a factor indicating the root extract: cucumber ("Cucumber") and bean ("Bean").

seeds a numeric vector indicating the total number of seeds.

germinated a numeric vector indicating the number of germinated seeds.

References

Crowder, M.J. (1978) Beta-binomial anova for proportions. *Journal of the Royal Statistical Society. Series C (Applied Statistics)* 27, 34-37.

Hinde, J. and Demetrio, C.G.B. (1998) Overdispersion: Models and estimation. *Computational Statistics & Data Analysis* 27, 151-170.

Examples

```
out <- aggregate(cbind(germinated,seeds) ~ extract + specie, data=orobanche, sum)
barplot(100*germinated/seeds ~ extract + specie, beside=TRUE, data=out, width=0.3,
        col=c("yellow","blue"), xlab="Specie", ylab="% of germinated seeds")
legend(0.3, 70, c("Bean","Cucumber"), fill=c("yellow","blue"), bty="n",
       cex=0.6, x.intersp=0.2, y.intersp=1)
```

`ossification` *Teratogenic effects of phenytoin and trichloropropene oxide*

Description

The data come from a 2x2 factorial design with 81 pregnant mice. In the experiment each pregnant mouse was randomly allocated to an control group and three treated groups, which received daily, by gastric gavages, 60 mg/kg of phenytoin, 100 mg/kg of trichloropropene oxide, or 60 mg/kg phenytoin and 100 mg/kg of trichloropropene oxide. On day 18 of gestation, fetuses were recovered, stained, and cleared. Then, by visual inspection, the presence or absence of ossification was determined for the different joints of the right and left forepaws. The purpose of the experiment was to investigate the synergy of phenytoin and trichloropropene oxide to produce ossification at the phalanges, that is, teratogenic effects. See Morel and Nagaraj (2012, page 103).

Usage

```
data(ossification)
```

Format

A data frame with 81 rows and 4 variables:

fetuses a numeric vector giving the number of fetuses showing ossification on the left middle third phalanx.

litter a numeric vector giving the litter size.

pht a factor giving the dose (mg/kg) of phenytoin: "0 mg/kg" or "60 mg/kg".

tcpo a factor giving the dose (mg/kg) of trichloropropene oxide: "0 mg/kg" or "100 mg/kg".

References

Morel, J.G. and Neerchal, N.K. (1997) Clustered binary logistic regression in teratology data using a finite mixture distribution. *Statistics in Medicine* 16, 2843-2853.

Morel, J.G. and Nagaraj, N.K. (2012) *Overdispersion Models in SAS*. SAS Institute Inc., Cary, North Carolina, USA.

Examples

```
boxplot(100*fetuses/litter ~ pht, data=subset(ossification, tcpo=="0 mg/kg"),
        at=c(1:2)-0.2, col="yellow", boxwex=0.25, outline=FALSE, xaxt="n",
        xlab="Dose of PHT", ylab="% of fetuses showing ossification")
boxplot(100*fetuses/litter ~ pht, data=subset(ossification, tcpo=="100 mg/kg"),
        add=TRUE, at=c(1:2)+0.2, col="blue", boxwex=0.25, outline=FALSE, xaxt="n")
axis(1, at=1:2, labels=levels(ossification$pht))
legend(0.1, 20, legend=c("0 mg/kg","100 mg/kg"), fill=c("yellow","blue"),
       bty="n", cex=0.7, x.intersp=0.2, y.intersp=1)
```

`overglm` *Alternatives to the Poisson and Binomial Regression Models under the presence of Overdispersion.*

Description

Allows to fit regression models based on the negative binomial, beta-binomial, and random-clumped binomial distributions, which are alternatives to the Poisson and binomial regression models under the presence of overdispersion.

Usage

```
overglm(
  formula,
  family = "nb1(log)",
  weights,
  data,
  subset,
  na.action = na.omit(),
  reltol = 1e-13,
  start = NULL,
  ...
)
```

Arguments

`formula`	a `formula` expression of the form `response ~ x1 + x2 + ...`, which is a symbolic description of the linear predictor of the model to be fitted to the data.
`family`	a character string which allows to specify the distribution to describe the response variable, as well as the link function to be used in the model for μ. The following distributions are supported: negative binomial I ("nb1"), negative binomial II ("nb2"), negative binomial ("nbf"), zero-truncated negative binomial I ("ztnb1"), zero-truncated negative binomial II ("ztnb2"), zero-truncated negative binomial ("ztnbf"), zero-truncated poisson ("ztpoi"), beta-binomial ("bb") and random-clumped binomial ("rcb"). Link functions available for these models are the same than those available in Poisson and binomial models via glm. See family documentation.

`weights`	an (optional) vector of positive "prior weights" to be used in the fitting process. The length of `weights` should be the same as the number of observations.
`data`	an (optional) `data frame` in which to look for variables involved in the `formula` expression, as well as for variables specified in the arguments `weights` and `subset`.
`subset`	an (optional) vector specifying a subset of individuals to be used in the fitting process.
`na.action`	a function which indicates what should happen when the data contain NAs. By default `na.action` is set to be `na.omit()`.
`reltol`	an (optional) positive value which represents the *relative convergence tolerance* for the BFGS method in optim. By default, `reltol` is set to be 1e-13.
`start`	an (optional) vector of starting values for the parameters in the linear predictor.
`...`	further arguments passed to or from other methods.

Details

The negative binomial distribution can be obtained as mixture of the Poisson and Gamma distributions. If $Y|\lambda$ ~ Poisson(λ), where E($Y|\lambda$) = Var($Y|\lambda$) = λ, and λ ~ Gamma(θ, ν), in which E(λ) = θ and Var(λ) = $\nu\theta^2$, then Y is distributed according to the negative binomial distribution. As follows, some special cases are described:

(1) If $\theta = \mu$ and $\nu = \phi$ then Y ~ Negative Binomial I, E(Y) = μ and Var(Y) = $\mu(1 + \phi\mu)$.

(2) If $\theta = \mu$ and $\nu = \phi/\mu$ then Y ~ Negative Binomial II, E(Y) = μ and Var(Y) = $\mu(1 + \phi)$.

(3) If $\theta = \mu$ and $\nu = \phi\mu^{\tau}$ then Y ~ Negative Binomial, E(Y) = μ and Var(Y) = $\mu(1 + \phi\mu^{\tau+1})$.

Therefore, the regression models based on the negative binomial and zero-truncated negative binomial distributions are alternatives under the presence of overdispersion to those based on the Poisson and zero-truncated Poisson distributions, respectively.

The beta-binomial distribution can be obtained as mixture of the binomial and beta distributions. If $mY|\pi$ ~ Binomial(m, π), where E($Y|\pi$) = π and Var($Y|\pi$) = $m^{-1}\pi(1-\pi)$, and π ~ Beta(μ, ϕ), in which E(π) = μ and Var(π) = $(\phi+1)^{-1}\mu(1-\mu)$, with $\phi > 0$, then mY ~ Beta-Binomial(m, μ, ϕ), so that E(Y) = μ and Var(Y) = $m^{-1}\mu(1-\mu)[1 + (\phi+1)^{-1}(m-1)]$. Therefore, the regression model based on the beta-binomial distribution is an alternative under the presence of overdispersion to the binomial regression model.

The random-clumped binomial distribution can be obtained as mixture of the binomial and Bernoulli distributions. If $mY|\pi$ ~ Binomial(m, π), where E($Y|\pi$) = π and Var($Y|\pi$) = $m^{-1}\pi(1-\pi)$, whereas $\pi = (1-\phi)\mu + \phi$ with probability μ, and $\pi = (1-\phi)\mu$ with probability $1-\mu$, in which E(π) = μ and Var(π) = $\phi^2\mu(1-\mu)$, with $\phi \in (0, 1)$, then mY ~ Random-clumped Binomial(m, μ, ϕ), so that E(Y) = μ and Var(Y) = $m^{-1}\mu(1-\mu)[1 + \phi^2(m-1)]$. Therefore, the regression model based on the random-clumped binomial distribution is an alternative under the presence of overdispersion to the binomial regression model.

In all cases, even in those where the response variable is described using a zero-truncated distribution, the fitted model is aimed to describe the way in which μ is dependent on some covariates. The parameter estimation is performed by using the maximum likelihood method. The model parameters are estimated by maximizing the log-likelihood function using the BFGS method available in the routine optim. The accuracy and speed of the BFGS method are increased because of the call to the routine optim is performed using the analytical instead of the numerical derivatives. The

estimate of the variance-covariance matrix is obtained as being minus the inverse of the (analytical) hessian matrix evaluated at the parameter estimates and the observed data.

A set of standard extractor functions for fitted model objects is available for objects of class *zeroinflation*, including methods to the generic functions such as `print`, `summary`, `model.matrix`, `estequa`, `coef`, `vcov`, `logLik`, `fitted`, `confint`, `AIC`, `BIC` and `predict`. In addition, the model fitted to the data may be assessed using functions such as anova.overglm, residuals.overglm, dfbeta.overglm, cooks.distance.overglm, localInfluence.overglm, gvif.overglm and envelope.overglm. The variable selection may be accomplished using the routine stepCriterion.overglm.

Value

an object of class *overglm* in which the main results of the model fitted to the data are stored, i.e., a list with components including

`coefficients`	a vector containing the parameter estimates,
`fitted.values`	a vector containing the estimates of $\mu_1, \ldots, \mu_n$,
`start`	a vector containing the starting values used,
`prior.weights`	a vector containing the case weights used,
`offset`	a vector containing the offset used,
`terms`	an object containing the terms objects,
`loglik`	the value of the log-likelihood function avaliated at the parameter estimates,
`estfun`	a vector containing the estimating functions evaluated at the parameter estimates and the observed data,
`formula`	the formula,
`levels`	the levels of the categorical regressors,
`contrasts`	an object containing the contrasts corresponding to levels,
`converged`	a logical indicating successful convergence,
`model`	the full model frame,
`y`	the response count vector,
`family`	an object containing the family object used,
`linear.predictors`	a vector containing the estimates of $g(\mu_1), \ldots, g(\mu_n)$,
`R`	a matrix with the Cholesky decomposition of the inverse of the variance-covariance matrix of all parameters in the model,

`call` the original function call,

References

Crowder, M. (1978) Beta-binomial anova for proportions, *Journal of the Royal Statistical Society Series C (Applied Statistics)* 27, 34-37.

Lawless, J.F. (1987) Negative binomial and mixed poisson regression, *The Canadian Journal of Statistics* 15, 209-225.

Morel, J.G. and Neerchal, N.K. (1997) Clustered binary logistic regression in teratology data using a finite mixture distribution, *Statistics in Medicine* 16, 2843-2853.

Morel, J.G. and Nagaraj, N.K. (2012) *Overdispersion Models in SAS*. SAS Institute Inc., Cary, North Carolina, USA.

See Also

zeroalt, zeroinf

Examples

```
### Example 1: Ability of retinyl acetate to prevent mammary cancer in rats
fit1 <- overglm(tumors ~ group, family="nb1(identity)", data=mammary)
summary(fit1)

### Example 2: Self diagnozed ear infections in swimmers
fit2 <- overglm(infections ~ frequency + location, family="nb1(log)", data=swimmers)
summary(fit2)

### Example 3: Urinary tract infections in HIV-infected men
fit3 <- overglm(episodes ~ cd4 + offset(log(time)), family="nb1(log)", data = uti)
summary(fit3)

### Example 4: Article production by graduate students in biochemistry PhD programs
bioChemists <- pscl::bioChemists
fit4 <- overglm(art ~ fem + kid5 + ment, family="nb1(log)", data = bioChemists)
summary(fit4)

### Example 5: Agents to stimulate cellular differentiation
fit5 <- overglm(cbind(cells,200-cells) ~ tnf + ifn, family="bb(logit)", data=cellular)
summary(fit5)

### Example 6: Teratogenic effects of phenytoin and trichloropropene oxide
model6 <- cbind(fetuses,litter-fetuses) ~ pht + tcpo
fit6 <- overglm(model6, family="rcb(cloglog)", data=ossification)
summary(fit6)

### Example 7: Germination of orobanche seeds
model7 <- cbind(germinated,seeds-germinated) ~ specie + extract
fit7 <- overglm(model7, family="rcb(cloglog)", data=orobanche)
summary(fit7)
```

predict.glmgee *Predictions for Generalized Estimating Equations*

Description

Produces predictions and optionally estimates standard errors of those predictions from a fitted generalized estimating equation.

Usage

```
## S3 method for class 'glmgee'
predict(
  object,
  ...,
  newdata,
  se.fit = FALSE,
  type = c("link", "response"),
  varest = c("robust", "df-adjusted", "model", "bias-corrected")
)
```

Arguments

object	an object of the class *glmgee*.
...	further arguments passed to or from other methods.
newdata	an (optional) data frame in which to look for variables with which to predict. If omitted, the fitted linear predictors are used.
se.fit	an (optional) logical switch indicating if standard errors are required. By default, se.fit is set to be FALSE.
type	an (optional) character string giving the type of prediction required. The default, "link", is on the scale of the linear predictors, and the alternative, "response", is on the scale of the response variable.
varest	an (optional) character string indicating the type of estimator which should be used to the variance-covariance matrix of the interest parameters. The available options are: robust sandwich-type estimator ("robust"), degrees-of-freedom-adjusted estimator ("df-adjusted"), bias-corrected estimator ("bias-corrected"), and the model-based or naive estimator ("model"). By default, varest is set to be "robust".

Value

A matrix with so many rows as newdata and one column with the predictions. If se.fit=TRUE then a second column with estimates standard errors is included.

Examples

```
###### Example 1: Effect of ozone-enriched atmosphere on growth of sitka spruces
mod1 <- size ~ poly(days,4) + treat
fit1 <- glmgee(mod1, id=tree, family=Gamma("log"), data=spruces, corstr="AR-1")
newdata1 <- data.frame(days=c(556,556),treat=as.factor(c("normal","ozone-enriched")))
predict(fit1,newdata=newdata1,type="response",se.fit=TRUE)

###### Example 2: Treatment for severe postnatal depression
mod2 <- depressd ~ visit + group
fit2 <- glmgee(mod2, id=subj, family=binomial("logit"), corstr="AR-1", data=depression)
newdata2 <- data.frame(visit=c(6,6),group=as.factor(c("placebo","estrogen")))
predict(fit2,newdata=newdata2,type="response",se.fit=TRUE)

###### Example 3: Treatment for severe postnatal depression (2)
mod3 <- dep ~ visit*group
fit3 <- glmgee(mod3, id=subj, family=gaussian("identity"), corstr="AR-1", data=depression)
newdata3 <- data.frame(visit=c(6,6),group=as.factor(c("placebo","estrogen")))
predict(fit3,newdata=newdata3,type="response",se.fit=TRUE)
```

`QIC` *QIC for Generalized Estimating Equations*

Description

Computes the quasi-likelihood under the independence model criterion (QIC) for one or more objects of the class glmgee.

Usage

```
QIC(..., k = 2, u = FALSE, verbose = TRUE)
```

Arguments

`...`	one or several objects of the class *glmgee*.
`k`	an (optional) non-negative value giving the magnitude of the penalty. By default, `k` is set to be 2.
`u`	an (optional) logical switch indicating if QIC should be replaced by QICu. By default, `u` is set to be FALSE.
`verbose`	an (optional) logical switch indicating if should the report of results be printed. By default, `verbose` is set to be TRUE.

Value

A `data.frame` with the values of -2*quasi-likelihood, the number of parameters in the linear predictor, and the value of QIC (or QICu if u=TRUE) for each *glmgee* object in the input.

References

Pan, W. (2001) Akaike's information criterion in generalized estimating equations, *Biometrics* 57, 120-125.

Hin, L.-Y. and Carey, V.J. and Wang, Y.-G. (2007) Criteria for Working–Correlation–Structure Selection in GEE: Assessment via Simulation. *The American Statistician* 61, 360–364.

See Also

CIC, GHYC, RJC, AGPC, SGPC

Examples

```
###### Example 1: Effect of ozone-enriched atmosphere on growth of sitka spruces
mod1 <- size ~ poly(days,4) + treat
fit1 <- glmgee(mod1, id=tree, family=Gamma("log"), data=spruces)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Stationary-M-dependent(2)")
fit4 <- update(fit1, corstr="Exchangeable")
QIC(fit1, fit2, fit3, fit4)

###### Example 2: Treatment for severe postnatal depression
mod2 <- depressd ~ visit + group
fit1 <- glmgee(mod2, id=subj, family=binomial("logit"), data=depression)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Stationary-M-dependent(2)")
fit4 <- update(fit1, corstr="Exchangeable")
QIC(fit1, fit2, fit3, fit4)

###### Example 3: Treatment for severe postnatal depression (2)
mod3 <- dep ~ visit*group
fit1 <- glmgee(mod3, id=subj, family=gaussian("identity"), data=depression)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Exchangeable")
QIC(fit1, fit2, fit3)
```

---

races *Hill races in Scotland*

Description

Each year the Scottish Hill Runners Association publishes a list of hill races in Scotland for the year. These data consist of record time, distance, and cumulative climb of 35 of those races. The aim of the statistical analysis of these data is to explain the differences between the record time of the races using their differences on distance and cumulative climb. See Agresti (2015, page 62).

Usage

```
data(races)
```

Format

A data frame with 35 rows and 4 variables:

race a character vector giving the names of the races.

distance a numeric vector giving the distance, in miles, of the races.

cclimb a numeric vector giving the cumulative climb, in thousands of feet, of the races.

rtime a numeric vector giving the record time, in minutes, of the races.

References

Agresti, A. (2015) *Foundations of Linear and Generalized Linear Models*. John Wiley & Sons, New Jersey.

Examples

```
races2 <- within(races,cli <- cut(cclimb, include.lowest=TRUE,
                                  breaks=quantile(cclimb, probs=c(0:2)/2),
                                  labels=c("low","high")))
with(races2,{
    plot(log(distance), log(rtime),
         col=apply(as.matrix(cli),1,function(x) switch(x,"low"="red","high"="blue")),
         pch=apply(as.matrix(cli),1,function(x) switch(x,"low"=15,"high"=16)))
   legend(0.7, 5.4, legend=c("low","high"), title="Cumulative climb", col=c("red","blue"),
           pch=c(15,16), bty="n", x.intersp=0.2, y.intersp=1)
})
```

---

residuals.glmgee *Residuals for Generalized Estimating Equations*

Description

Calculates residuals for a fitted generalized estimating equation.

Usage

```
## S3 method for class 'glmgee'
residuals(
  object,
  ...,
  type = c("mahalanobis", "pearson", "deviance"),
  plot.it = FALSE,
  identify
)
```

Arguments

object	a object of the class *glmgee*.
...	further arguments passed to or from other methods
type	an (optional) character string giving the type of residuals which should be returned. The available options are: (1) "pearson"; (2) "deviance"; (3) the distance between the observed response vector and the fitted mean vector using a metric based on the product between the cluster size and fitted variance-covariance matrix ("mahalanobis"). By default, type is set to be "mahalanobis".
plot.it	an (optional) logical switch indicating if a plot of the residuals is required. By default, plot.it is set to be FALSE.
identify	an (optional) integer value indicating the number of individuals/clusters to identify on the plot of residuals. This is only appropriate when plot.it=TRUE.

Value

A vector with the observed residuals type type.

Examples

```
###### Example 1: Effect of ozone-enriched atmosphere on growth of sitka spruces
mod1 <- size ~ poly(days,4) + treat
fit1 <- glmgee(mod1, id=tree, family=Gamma("log"), data=spruces, corstr="AR-1")
### Plot to assess the adequacy of the chosen variance function
residuals(fit1, type="deviance", plot.it=TRUE, col="red", pch=20, col.lab="blue",
          col.axis="blue", col.main="black", family="mono", cex=0.8)
### Plot to identify trees suspicious to be outliers
residuals(fit1, type="mahalanobis", plot.it=TRUE, col="red", pch=20, col.lab="blue",
          col.axis="blue", col.main="black", family="mono", cex=0.8)

###### Example 2: Treatment for severe postnatal depression
mod2 <- depressd ~ visit + group
fit2 <- glmgee(mod2, id=subj, family=binomial("logit"), corstr="AR-1", data=depression)
### Plot to identify women suspicious to be outliers
residuals(fit2, type="mahalanobis", plot.it=TRUE, col="red", pch=20, col.lab="blue",
          col.axis="blue", col.main="black", family="mono", cex=0.8)

###### Example 3: Treatment for severe postnatal depression (2)
mod3 <- dep ~ visit*group
fit3 <- glmgee(mod3, id=subj, family=gaussian("identity"), corstr="AR-1", data=depression)
### Plot to assess the adequacy of the chosen variance function
residuals(fit3, type="pearson", plot.it=TRUE, col="red", pch=20, col.lab="blue",
          col.axis="blue", col.main="black", family="mono", cex=0.8)
### Plot to identify women suspicious to be outliers
residuals(fit3, type="mahalanobis", plot.it=TRUE, col="red", pch=20, col.lab="blue",
          col.axis="blue", col.main="black", family="mono", cex=0.8)
```

`residuals.overglm` *Residuals for alternatives to the Poisson and Binomial Regression Models under the presence of Overdispersion.*

Description

Computes various types of residuals to assess the individual quality of model fit for regression models based on the negative binomial, beta-binomial, and random-clumped binomial distributions, which are alternatives to the Poisson and binomial regression models under the presence of overdispersion.

Usage

```
## S3 method for class 'overglm'
residuals(
  object,
  type = c("quantile", "standardized", "response"),
  plot.it = FALSE,
  identify,
  ...
)
```

Arguments

`object`	an object of class *overglm*.
`type`	an (optional) character string which allows to specify the required type of residuals. The available options are: (1) the difference between the observed response and the fitted mean ("response"); (2) the standardized difference between the observed response and the fitted mean ("standardized"); and (3) the randomized quantile residual ("quantile"). By default, `type` is set to be "quantile".
`plot.it`	an (optional) logical switch indicating if the plot of residuals versus the fitted values is required. By default, `plot.it` is set to be FALSE.
`identify`	an (optional) positive integer value indicating the number of individuals to identify on the plot of residuals versus the fitted values. This is only appropriate if `plot.it=TRUE`.
`...`	further arguments passed to or from other methods. If `plot.it=TRUE` then `...` may be used to include graphical parameters to customize the plot. For example, `col`, `pch`, `cex`, `main`, `sub`, `xlab`, `ylab`.

Value

A vector with the observed `type`-type residuals.

References

Dunn P.K. and Smyth G.K. (1996) Randomized Quantile Residuals. *Journal of Computational and Graphical Statistics*, 5, 236-244.

Examples

```
###### Example 1: Self diagnozed ear infections in swimmers
fit1 <- overglm(infections ~ frequency + location, family="nb1(log)", data=swimmers)
residuals(fit1, type="quantile", plot.it=TRUE, col="red", pch=20, col.lab="blue",
          col.axis="blue", col.main="black", family="mono", cex=0.8)

###### Example 2: Article production by graduate students in biochemistry PhD programs
bioChemists <- pscl::bioChemists
fit2 <- overglm(art ~ fem + kid5 + ment, family="nb1(log)", data = bioChemists)
residuals(fit2, type="quantile", plot.it=TRUE, col="red", pch=20, col.lab="blue",
          col.axis="blue", col.main="black", family="mono", cex=0.8)

###### Example 3: Agents to stimulate cellular differentiation
fit3 <- overglm(cbind(cells,200-cells) ~ tnf + ifn, family="bb(logit)", data=cellular)
residuals(fit3, type="quantile", plot.it=TRUE, col="red", pch=20, col.lab="blue",
          col.axis="blue", col.main="black", family="mono", cex=0.8)
```

`residuals.zeroinflation` *Residuals in Regression Models to deal with Zero-Excess in Count Data*

Description

Computes various types of residuals to assess the individual quality of model fit in regression models to deal with zero-excess in count data.

Usage

```
## S3 method for class 'zeroinflation'
residuals(
  object,
  type = c("quantile", "standardized", "response"),
  plot.it = FALSE,
  identify,
  ...
)
```

Arguments

`object`	an object of class *zeroinflation*.
`type`	an (optional) character string which allows to specify the required type of residuals. The available options are: (1) the difference between the observed response and the fitted mean ("response"); (2) the standardized difference between the observed response and the fitted mean ("standardized"); (3) the randomized quantile residual ("quantile"). By default, `type` is set to be "quantile".

plot.it	an (optional) logical switch indicating if the plot of residuals versus the fitted values is required. By default, plot.it is set to be FALSE.
identify	an (optional) positive integer value indicating the number of individuals to identify on the plot of residuals versus the fitted values. This is only appropriate if plot.it=TRUE.
...	further arguments passed to or from other methods. If plot.it=TRUE then ... may be used to include graphical parameters to customize the plot. For example, col, pch, cex, main, sub, xlab, ylab.

Value

A vector with the observed residuals type type.

References

Dunn P.K. and Smyth G.K. (1996) Randomized Quantile Residuals. *Journal of Computational and Graphical Statistics*, 5, 236-244.

Examples

```
####### Example 1: Self diagnozed ear infections in swimmers
fit1 <- zeroalt(infections ~ frequency | location, family="nb1(log)", data=swimmers)
residuals(fit1, type="quantile", col="red", pch=20, col.lab="blue", plot.it=TRUE,
          col.axis="blue", col.main="black", family="mono", cex=0.8)

####### Example 2: Article production by graduate students in biochemistry PhD programs
bioChemists <- pscl::bioChemists
fit2 <- zeroinf(art ~ fem + kid5 + ment | ment, family="nb1(log)", data = bioChemists)
residuals(fit2, type="quantile", col="red", pch=20, col.lab="blue", plot.it=TRUE,
          col.axis="blue", col.main="black", family="mono", cex=0.8)
```

---

residuals2 *Residuals for Linear and Generalized Linear Models*

Description

Computes residuals for a fitted linear or generalized linear model.

Usage

```
residuals2(object, type, standardized = FALSE, plot.it = TRUE, identify, ...)
```

Arguments

`object`	a object of the class *lm* or *glm*.
`type`	an (optional) character string giving the type of residuals which should be returned. The available options for LMs are: (1) externally studentized ("external"); (2) internally studentized ("internal") (default). The available options for GLMs are: (1) "pearson"; (2) "deviance"; (3) "quantile" (default).
`standardized`	an (optional) logical switch indicating if the residuals should be standardized by dividing by the square root of $(1 - h)$, where h is a measure of leverage. By default, `standardized` is set to be FALSE.
`plot.it`	an (optional) logical switch indicating if a plot of the residuals is required. By default, `plot.it` is set to be FALSE.
`identify`	an (optional) integer value indicating the number of individuals to identify on the plot of residuals. This is only appropriate when `plot.it=TRUE`.
`...`	further arguments passed to or from other methods

Value

A vector with the observed residuals type `type`.

Examples

```
###### Example 1: Species richness in plots
fit1 <- lm(Species ~ Biomass + pH, data=richness)
residuals2(fit1, type="external", col="red", pch=20, col.lab="blue", plot.it=TRUE,
           col.axis="blue", col.main="black", family="mono", cex=0.8)

###### Example 2: Lesions of Aucuba mosaic virus
fit2 <- glm(lesions ~ time, family=poisson, data=aucuba)
residuals2(fit2, type="quantile", col="red", pch=20, col.lab="blue", plot.it=TRUE,
           col.axis="blue",col.main="black",family="mono",cex=0.8)
```

`richness` *Species richness*

Description

In these data the response is the species richness represented by a count of the number of plant species on plots that have different biomass and three different soil pH levels: low, mid, and high. See Crawley (2007, page 534).

Usage

```
data(richness)
```

Format

A data frame with 90 rows and 3 variables:

Biomass a numeric vector giving the value of the biomass in the plots.

pH a factor giving the soil pH level in the plots: "low", "mid", and "high".

Species a numeric vector giving the number of plant species in the plots.

References

Crawley, M.J. (2007) *The R Book*. John Wiley & Sons, Chichester.

Examples

```
with(richness,{
  plot(Biomass, Species,
     col=apply(as.matrix(pH),1,function(x) switch(x,"low"="red","mid"="black","high"="blue")),
       pch=apply(as.matrix(pH),1,function(x) switch(x,"low"=15,"mid"=16,"high"=17)))
  legend(8.2, 43, legend=c("low","mid","high"), col=c("red","black","blue"),
         pch=c(15,16,17), bty="n", cex=0.8, title="pH level")
})
```

---

rinse *Dental Clinical Trial*

Description

These data arose from a dental clinical study. In this trial, subjects were generally healthy adult male and female volunteers, ages 18–55, with pre-existing plaque but without advanced periodontal disease. Prior to entry, subjects were screened for a minimum of 20 sound, natural teeth and a minimum mean plaque index of 2.0. Subjects with gross oral pathology or on antibiotic, antibacterial, or anti-inflammatory therapy were excluded from the study. One hundred nine volunteers were randomized in a double-blinded way to one of two new mouth rinses (A and B) or to a control mouth rinse. Plaque was scored at baseline, at 3 months, and at 6 months by the Turesky modification of the Quigley-Hein index, a continuous measure. Four subjects had missing plaque scores. The main objective of the analysis is to measure the effectiveness of the three mouth rinses in inhibiting the development of dental plaque.

Usage

```
data(rinse)
```

Format

A data frame with 315 rows and 7 variables:

subject a character string giving the identifier of the volunteer.

gender a factor indicating the gender of the volunteer: "Female" and "Male".

age a numeric vector indicating the age of the volunteer.

rinse a factor indicating the type of rinse used by the volunteer: "Placebo", "A" and "B".

smoke a factor indicating if the volunteer smoke: "Yes" and "No".

time a numeric vector indicating the time (in months) since the treatment began.

score a numeric vector giving the subject's score of plaque.

References

Hadgu, A. and Koch, G. (1999) Application of generalized estimating equations to a dental randomized clinical trial. *Journal of Biopharmaceutical Statistics* 9, 161-178.

Examples

```
boxplot(score ~ time, data=subset(rinse,rinse=="Placebo"), at=c(1:3)-0.2,
 ylim=c(0,3.3), col="yellow", boxwex=0.15, outline=FALSE, xaxt="n", xlim=c(0.8,3.2))
boxplot(score ~ time, data=subset(rinse,rinse=="A"), add=TRUE,
        at=c(1:3), col="gray", boxwex=0.15, outline=FALSE, xaxt="n")
boxplot(score ~ time, data=subset(rinse,rinse=="B"), add=TRUE,
        at=c(1:3)+0.2, col="blue", boxwex=0.15, outline=FALSE, xaxt="n")
axis(1, at=1:3, labels=unique(rinse$time))
legend(0.7, 1, legend=c("Placebo","A","B"), fill=c("yellow","gray","blue"),
       bty="n", cex=0.6)
```

RJC *Rotnitzky–Jewell's Criterion for Generalized Estimating Equations*

Description

Computes the Rotnitzky–Jewell's criterion (RJC) for one or more objects of the class glmgee.

Usage

```
RJC(..., verbose = TRUE)
```

Arguments

`...`	one or several objects of the class *glmgee*.
`verbose`	an (optional) logical switch indicating if should the report of results be printed. By default, `verbose` is set to be TRUE.

Value

A `data.frame` with the values of the RJC for each *glmgee* object in the input.

References

Hin, L.-Y. and Carey, V.J. and Wang, Y.-G. (2007) Criteria for Working–Correlation–Structure Selection in GEE: Assessment via Simulation. *The American Statistician* 61, 360-364.

See Also

QIC, CIC, GHYC, AGPC, SGPC

Examples

```
###### Example 1: Effect of ozone-enriched atmosphere on growth of sitka spruces
mod1 <- size ~ poly(days,4) + treat
fit1 <- glmgee(mod1, id=tree, family=Gamma("log"), data=spruces)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Stationary-M-dependent(2)")
fit4 <- update(fit1, corstr="Exchangeable")
RJC(fit1, fit2, fit3, fit4)

###### Example 2: Treatment for severe postnatal depression
mod2 <- depressd ~ visit + group
fit1 <- glmgee(mod2, id=subj, family=binomial("logit"), data=depression)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Stationary-M-dependent(2)")
fit4 <- update(fit1, corstr="Exchangeable")
RJC(fit1, fit2, fit3, fit4)

###### Example 3: Treatment for severe postnatal depression (2)
mod3 <- dep ~ visit*group
fit1 <- glmgee(mod3, id=subj, family=gaussian("identity"), data=depression)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Exchangeable")
RJC(fit1, fit2, fit3)
```

ROCc *The Receiver Operating Characteristic (ROC) Curve*

Description

Computes the exact area under the ROC curve (AUROC), the Gini coefficient, and the Kolmogorov-Smirnov (KS) statistic for a binary classifier. Optionally, this function can plot the ROC curve, that is, the plot of the estimates of Sensitivity versus the estimates of 1-Specificity.

Usage

```
ROCc(object, plot.it = TRUE, verbose = TRUE, ...)
```

Arguments

`object`	a matrix with two columns: the first one is a numeric vector of 1's and 0's indicating whether each row is a "success" or a "failure"; the second one is a numeric vector of values indicating the probability (or propensity score) of each row to be a "success". Optionally, `object` can be an object of the class glm which is obtained from the fit of a generalized linear model where the distribution of the response variable is assumed to be binomial.

plot.it	an (optional) logical switch indicating if the plot of the ROC curve is required or just the data matrix in which it is based. By default, plot.it is set to be TRUE.
verbose	an (optional) logical switch indicating if should the report of results be printed. By default, verbose is set to be TRUE.
...	further arguments passed to or from other methods. For example, if plot.it=TRUE then ... may to include graphical parameters as col, pch, cex, main, sub, xlab, ylab.

Value

A list which contains the following objects:

- roc: A matrix with the Cutoffs and the associated estimates of Sensitivity and Specificity.
- auroc: The exact area under the ROC curve.
- gini: The value of the Gini coefficient computed as 2(auroc-0.5).
- ks: The value of the Kolmogorov-Smirnov statistic computed as the maximum value of |1-Sensitivity-Specificity|.

References

Hanley, J.A. and McNeil, B.J. (1982) The Meaning and Use of the Area under a Receiver Operating Characteristic (ROC) Curve. *Radiology* 143, 29–36.

Examples

```
###### Example: Patients with burn injuries
burn1000 <- aplore3::burn1000

### splitting the sample: 70% for the training sample and 30% for the validation sample
burn1000 <- within(burn1000, sampleof <- "validation")
s <- sample(nrow(burn1000),nrow(burn1000)*0.7)
burn1000$sampleof[s] <- "training"

training <- subset(burn1000,sampleof=="training")
fit <- glm(death ~ age*inh_inj + tbsa*inh_inj, family=binomial("logit"), data=training)

### ROC curve for the training sample
ROCc(fit, col="red", col.lab="blue", col.axis="black", col.main="black", family="mono")

validation <- subset(burn1000, sampleof=="validation")
probs <- predict(fit, newdata=validation, type="response")
responses <- with(validation, ifelse(death=="Dead",1,0))

### ROC curve for the validation sample
ROCc(cbind(responses,probs), col="red", col.lab="blue", col.axis="black",
     col.main="black", family="mono")
```

SGPC *SGPC for Generalized Estimating Equations*

Description

Computes the Schwarz-type penalized Gaussian pseudo-likelihood criterion (SGPC) for one or more objects of the class glmgee.

Usage

```
SGPC(..., verbose = TRUE)
```

Arguments

`...`	one or several objects of the class *glmgee*.
`verbose`	an (optional) logical switch indicating if should the report of results be printed. By default, `verbose` is set to be TRUE.

Value

A `data.frame` with the values of the gaussian pseudo-likelihood, the number of parameters in the linear predictor plus the number of parameters in the correlation matrix, and the value of SGPC for each *glmgee* object in the input.

References

Carey, V.J. and Wang, Y.-G. (2011) Working covariance model selection for generalized estimating equations. *Statistics in Medicine* 30, 3117-3124.

Zhu, X. and Zhu, Z. (2013) Comparison of Criteria to Select Working Correlation Matrix in Generalized Estimating Equations. *Chinese Journal of Applied Probability and Statistics* 29, 515-530.

Fu, L. and Hao, Y. and Wang, Y.-G. (2018) Working correlation structure selection in generalized estimating equations. *Computational Statistics* 33, 983-996.

See Also

QIC, CIC, RJC, GHYC, AGPC

Examples

```
###### Example 1: Effect of ozone-enriched atmosphere on growth of sitka spruces
mod1 <- size ~ poly(days,4) + treat
fit1 <- glmgee(mod1, id=tree, family=Gamma("log"), data=spruces)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Stationary-M-dependent(2)")
fit4 <- update(fit1, corstr="Exchangeable")
SGPC(fit1, fit2, fit3, fit4)

###### Example 2: Treatment for severe postnatal depression
```

```
mod2 <- depressd ~ visit + group
fit1 <- glmgee(mod2, id=subj, family=binomial("logit"), data=depression)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Stationary-M-dependent(2)")
fit4 <- update(fit1, corstr="Exchangeable")
SGPC(fit1, fit2, fit3, fit4)

###### Example 3: Treatment for severe postnatal depression (2)
mod3 <- dep ~ visit*group
fit1 <- glmgee(mod3, id=subj, family=gaussian("identity"), data=depression)
fit2 <- update(fit1, corstr="AR-1")
fit3 <- update(fit1, corstr="Exchangeable")
SGPC(fit1, fit2, fit3)
```

`skincancer` *Skin cancer in women*

Description

The data describe the incidence of nonmelanoma skin cancer for women stratified by age in Minneapolis (St. Paul) and Dallas (Fort Worth). See Kleinbaum et al. (2013, page 751).

Usage

```
data(skincancer)
```

Format

A data frame with 16 rows and 4 variables:

cases a numeric vector giving the nonmelanoma skin cancer counts.

city a factor giving the city to which correspond the skin cancer counts: "St.Paul" and "Ft.Worth".

age a factor giving the age range to which correspond the skin cancer counts: "15-24", "25-34", "35-44", "45-54", "55-64", "65-74", "75-84" and "85+".

population a numeric vector giving the population of women.

References

Kleinbaum, D. and Kupper, L. and Nizam, A. and Rosenberg, E.S. (2013) *Applied Regression Analysis and other Multivariable Methods, Fifth Edition*, Cengage Learning, Boston.

Examples

```
barplot(1000*cases/population ~ city + age, beside=TRUE,
        col=c("yellow","blue"), data=skincancer)
legend(1.5, 8.5, legend=c("St.Paul","Ft.Worth"), title="City",
       fill=c("yellow","blue"), bty="n", cex=0.9)
```

spruces *Effect of ozone-enriched atmosphere on growth of sitka spruces*

Description

The main objective of the analysis of these data is to assess the effect of the ozone pollution on the tree growth. As ozone pollution is common in urban areas, the impact of increased ozone concentrations on tree growth is of considerable interest. The response variable is tree size, where size is conventionally measured by the product of tree height and stem diameter squared. In a first group, a total of 54 trees were grown under an ozone-enriched atmosphere, that is, ozone exposure at 70 parts per billion, whereas in a second group, 25 were grown under a normal atmosphere. The size of each tree was observed 13 times across the time, that is, 152, 174, 201, 227, 258, 469, 496, 528, 556, 579, 613, 639 and 674 days since the beginning of the experiment. Hence, the objective is to compare the growth patterns of the trees under the two conditions. See Diggle et al. (2002, page 4).

Usage

```
data(spruces)
```

Format

A data frame with 1027 rows and 4 variables:

tree a factor giving an unique identifier for each tree.

days a numeric vector giving the number of days since the beginning of the experiment.

size a numeric vector giving an estimate of the volume of the tree trunk.

treat a factor giving the treatment received for each tree: "normal" and "ozone-enriched".

References

Diggle, P.J. and Heagarty, P. and Liang, K.-Y. and Zeger, S.L. (2002) *Analysis of Longitudinal Data*. Oxford University Press, Oxford.

Crainiceanu, C.M. and Ruppert, D. and Wand, M.P. (2005). Bayesian Analysis for Penalized Spline Regression Using WinBUGS. *Journal of Statistical Software* 14(14).

Examples

```
boxplot(size ~ days, data=subset(spruces,treat=="normal"), at=c(1:13)-0.2,
        col="yellow", boxwex=0.3, outline=FALSE, xaxt="n", xlim=c(0.9,13.1))
boxplot(size ~ days, data=subset(spruces,treat=="ozone-enriched"), add=TRUE,
        at=c(1:13)+0.2, col="blue", boxwex=0.3, outline=FALSE, xaxt="n")
axis(1, at=1:13, labels=unique(spruces$days))
axis(2, at=seq(0,1500,250), labels=seq(0,1500,250))
legend(0.3, 1500, legend=c("normal","ozone-enriched"), fill=c("yellow","blue"),
       bty="n", cex=0.7, x.intersp=0.2, y.intersp=1)
```

stepCriterion *Variable selection in regression models from a chosen criterion*

Description

Generic function for selecting variables from a fitted regression model using a chosen criterion.

Usage

```
stepCriterion(model, ...)
```

Arguments

model	a fitted model object.
...	further arguments passed to or from other methods.

Value

A list which includes the descriptions of the linear predictors of the initial and final models as well as the criterion used to compare the candidate models.

stepCriterion.glm *Variable Selection in Generalized Linear Models*

Description

Performs variable selection in generalized linear models using hybrid versions of forward stepwise and backward stepwise.

Usage

```
## S3 method for class 'glm'
stepCriterion(
  model,
  criterion = c("bic", "aic", "adjr2", "p-value", "qicu"),
  test = c("wald", "lr", "score", "gradient"),
  direction = c("forward", "backward"),
  levels = c(0.05, 0.05),
  trace = TRUE,
  scope,
  ...
)
```

Arguments

`model`	an object of the class *glm*.
`criterion`	an (optional) character string indicating the criterion which should be used to compare the candidate models. The available options are: AIC ("aic"), BIC ("bic"), adjusted deviance-based R-squared ("adjr2"), and p-value of the `test` test ("p-value"). By default, `criterion` is set to be "bic".
`test`	an (optional) character string indicating the statistical test which should be used to compare nested models. The available options are: Wald ("wald"), Rao's score ("score"), likelihood-ratio ("lr") and gradient ("gradient") tests. By default, `test` is set to be "wald".
`direction`	an (optional) character string indicating the type of procedure which should be used. The available options are: hybrid backward stepwise ("backward") and hybrid forward stepwise ("forward"). By default, `direction` is set to be "forward".
`levels`	an (optional) two-dimensional vector of values in the interval $(0, 1)$ indicating the levels at which the variables should in and out from the model. This is only appropiate if `criterion`="p-value". By default, `levels` is set to be `c(0.05,0.05)`.
`trace`	an (optional) logical switch indicating if should the stepwise reports be printed. By default, `trace` is set to be TRUE.
`scope`	an (optional) list, containing components `lower` and `upper`, both formula-type objects, indicating the range of models which should be examined in the stepwise search. By default, `lower` is a model with no predictors and `upper` is the linear predictor of the model in `model`.
`...`	further arguments passed to or from other methods. For example, k, that is, the magnitude of the penalty in the AIC/QICu, which by default is set to be 2.

Details

The "hybrid forward stepwise" algorithm starts with the simplest model (which may be specified at the argument `scope`, and by default, is a model whose parameters in the linear predictor, except the intercept, if any, are set to be 0), and then the candidate models are builded by hierarchically adding effects in the linear predictor, whose "relevance" and/or "importance" in the model fit is assessed by comparing nested models (that is, by comparing the models with and without the added effect) using a criterion previously specified. If an effect is added to the model then this strategy may also remove any effect which, according to the criterion previously specified, no longer provide an improvement in the model fit. That process remain until no more effects may be included or excluded.

The "hybrid backward stepwise" algorithm works similarly.

Value

a list list with components including

`initial`	a character string indicating the linear predictor of the "initial model",

`direction` a character string indicating the type of procedure which was used,

`criterion` a character string indicating the criterion used to compare the candidate models,

`final` a character string indicating the linear predictor of the "final model",

References

James, G. and Witten, D. and Hastie, T. and Tibshirani, R. (2013, page 210) An Introduction to Statistical Learning with Applications in R, Springer, New York.

See Also

stepCriterion.lm, stepCriterion.overglm, stepCriterion.glmgee

Examples

```
###### Example 1: Fuel consumption of automobiles
Auto <- ISLR::Auto
Auto2 <- within(Auto, origin <- factor(origin))
mod <- mpg ~ cylinders + displacement + acceleration + origin + horsepower*weight
fit1 <- glm(mod, family=inverse.gaussian("log"), data=Auto2)
stepCriterion(fit1, direction="forward", criterion="p-value", test="lr")
stepCriterion(fit1, direction="backward", criterion="bic")

###### Example 2: Patients with burn injuries
burn1000 <- aplore3::burn1000
burn1000 <- within(burn1000, death <- factor(death, levels=c("Dead","Alive")))
upper <- ~ age + gender + race + tbsa + inh_inj + flame + age*inh_inj + tbsa*inh_inj
lower <- ~ 1
fit2 <- glm(death ~ age + gender + race + tbsa + inh_inj, family=binomial("logit"), data=burn1000)
stepCriterion(fit2, direction="backward", criterion="bic", scope=list(lower=lower,upper=upper))
stepCriterion(fit2, direction="forward", criterion="p-value", test="score")

###### Example 3: Skin cancer in women
upper <- cases ~ city + age + city*age
fit3 <- glm(upper, family=poisson("log"), offset=log(population), data=skincancer)
stepCriterion(fit3, direction="backward", criterion="aic", scope=list(lower=~ 1,upper=upper))
stepCriterion(fit3, direction="forward", criterion="p-value", test="lr")
```

---

stepCriterion.glmgee *Variable selection in Generalized Estimating Equations*

Description

Performs variable selection in generalized estimating equations using hybrid versions of forward stepwise and backward stepwise.

Usage

```
## S3 method for class 'glmgee'
stepCriterion(
  model,
  criterion = c("p-value", "qic", "qicu", "adjr2", "agpc", "sgpc"),
  test = c("wald", "score"),
  direction = c("forward", "backward"),
  levels = c(0.05, 0.05),
  trace = TRUE,
  scope,
  digits = 5,
  varest = c("robust", "df-adjusted", "model", "bias-corrected"),
  ...
)
```

Arguments

`model`	an object of the class glmgee which is obtained from the fit of a generalized estimating equation.
`criterion`	an (optional) character string indicating the criterion which should be used to compare the candidate models. The available options are: QIC ("qic"), QICu ("qicu"), adjusted deviance-based R-squared ("adjr2"), Akaike-type penalized gaussian pseudo-likelihood criterion ("agpc"), Schwarz-type penalized gaussian pseudo-likelihood criterion ("sgpc") and *p*-value of the `test` test ("p-value"). By default, `criterion` is set to be "p-value".
`test`	an (optional) character string indicating the statistical test which should be used to compare nested models. The available options are: Wald ("wald") and generalized score ("score") tests. By default, `test` is set to be "wald".
`direction`	an (optional) character string indicating the type of procedure which should be used. The available options are: hybrid backward stepwise ("backward") and hybrid forward stepwise ("forward"). By default, `direction` is set to be "forward".
`levels`	an (optional) two-dimensional vector of values in the interval $(0, 1)$ indicating the levels at which the variables should in and out from the model. This is only appropiate if `criterion`="p-value". By default, `levels` is set to be `c(0.05,0.05)`.
`trace`	an (optional) logical switch indicating if should the stepwise reports be printed. By default, `trace` is set to be TRUE.
`scope`	an (optional) list, containing components `lower` and `upper`, both formula-type objects, indicating the range of models which should be examined in the stepwise search. By default, `lower` is a model with no predictors and `upper` is the linear predictor of the model in `model`.
`digits`	an (optional) integer indicating the number of digits which should be used to print the most of the criteria to compare the candidate models. By default, `digits` is set to be 5.

varest	an (optional) character string indicating the type of estimator which should be used to the variance-covariance matrix of the interest parameters in the Wald-type test. The available options are: robust sandwich-type estimator ("robust"), degrees-of-freedom-adjusted estimator ("df-adjusted"), bias-corrected estimator ("bias-corrected"), and the model-based or naive estimator ("model"). By default, varest is set to be "robust".
...	further arguments passed to or from other methods. For example, k, that is, the magnitude of the penalty in the AGPC, which by default is set to be 2.

Value

A list which contains the following objects:

- initial: a character string indicating the linear predictor of the "initial model".
- direction: a character string indicating the type of procedure which was used.
- criterion: a character string indicating the criterion used to compare the candidate models.
- final: a character string indicating the linear predictor of the "final model".

References

James, G. and Witten, D. and Hastie, T. and Tibshirani, R. (2013, page 210) *An Introduction to Statistical Learning with Applications in R*. Springer, New York.

Jianwen, X. and Jiamao, Z. and Liya, F. (2019) Variable selection in generalized estimating equations via empirical likelihood and Gaussian pseudo-likelihood. *Communications in Statistics - Simulation and Computation* 48, 1239-1250.

See Also

stepCriterion.lm, stepCriterion.glm, stepCriterion.overglm

Examples

```
###### Example 1: Effect of ozone-enriched atmosphere on growth of sitka spruces
mod <- size ~ poly(days,4)*treat
fit1 <- glmgee(mod, id=tree, family=Gamma("log"), data=spruces, corstr="AR-1")
stepCriterion(fit1, criterion="p-value", direction="forward", scope=list(lower=~1,upper=mod))

###### Example 2: Treatment for severe postnatal depression
mod <- depressd ~ visit*group
fit2 <- glmgee(mod, id=subj, family=binomial("logit"), corstr="AR-1", data=depression)
stepCriterion(fit2, criterion="adjr2", direction="forward", scope=list(lower=~1,upper=mod))

###### Example 3: Treatment for severe postnatal depression (2)
mod <- dep ~ visit*group
fit2 <- glmgee(mod, id=subj, family=gaussian("identity"), corstr="AR-1", data=depression)
stepCriterion(fit2, criterion="adjr2", direction="forward", scope=list(lower=~1,upper=mod))
```

stepCriterion.lm *Variable Selection in Normal Linear Models*

Description

Performs variable selection in normal linear models using a hybrid versions of forward stepwise and backward stepwise.

Usage

```
## S3 method for class 'lm'
stepCriterion(
  model,
  criterion = c("bic", "aic", "adjr2", "prdr2", "cp", "p-value"),
  direction = c("forward", "backward"),
  levels = c(0.05, 0.05),
  trace = TRUE,
  scope,
  ...
)
```

Arguments

model	an object of the class *lm*.
criterion	an (optional) character string indicating the criterion which should be used to compare the candidate models. The available options are: AIC ("aic"), BIC ("bic"), adjusted R-squared ("adjr2"), predicted R-squared ("prdr2"), Mallows' CP ("cp") and *p*-value of the F test ("p-value"). By default, criterion is set to be "bic".
direction	an (optional) character string indicating the type of procedure which should be used. The available options are: hybrid backward stepwise ("backward") and hybrid forward stepwise ("forward"). By default, direction is set to be "forward".
levels	an (optional) two-dimensional vector of values in the interval $(0, 1)$ indicating the levels at which the variables should in and out from the model. This is only appropiate if criterion="p-value". By default, levels is set to be c(0.05,0.05).
trace	an (optional) logical switch indicating if should the stepwise reports be printed. By default, trace is set to be TRUE.
scope	an (optional) list containing components lower and upper, both formula-type objects, indicating the range of models which should be examined in the stepwise search. By default, lower is a model with no predictors and upper is the linear predictor of the model in model.
...	further arguments passed to or from other methods. For example, k, that is, the magnitude of the penalty in the AIC/QICu, which by default is set to be 2.

Details

The "hybrid forward stepwise" algorithm starts with the simplest model (which may be specified at the argument scope, and by default, is a model whose parameters in the linear predictor, except the intercept, if any, are set to be 0), and then the candidate models are builded by hierarchically adding effects in the linear predictor, whose "relevance" and/or "importance" in the model fit is assessed by comparing nested models (that is, by comparing the models with and without the added effect) using a criterion previously specified. If an effect is added to the model then this strategy may also remove any effect which, according to the criterion previously specified, no longer provide an improvement in the model fit. That process remain until no more effects may be included or excluded.

The "hybrid backward stepwise" algorithm works similarly.

Value

a list list with components including

`initial`	a character string indicating the linear predictor of the "initial model",
`direction`	a character string indicating the type of procedure which was used,
`criterion`	a character string indicating the criterion used to compare the candidate models,
`final`	a character string indicating the linear predictor of the "final model",

References

James, G. and Witten, D. and Hastie, T. and Tibshirani, R. (2013, page 210) An Introduction to Statistical Learning with Applications in R, Springer, New York.

See Also

stepCriterion.glm, stepCriterion.overglm, stepCriterion.glmgee

stepCriterion.glm, stepCriterion.overglm, stepCriterion.glmgee

Examples

```
###### Example 1: New York air quality measurements
fit1 <- lm(log(Ozone) ~ Solar.R + Temp + Wind, data=airquality)
scope=list(lower=~1, upper=~Solar.R*Temp*Wind)
stepCriterion(fit1, direction="forward", criterion="adjr2", scope=scope)
stepCriterion(fit1, direction="forward", criterion="bic", scope=scope)
stepCriterion(fit1, direction="forward", criterion="p-value", scope=scope)

###### Example 2: Fuel consumption of automobiles
fit2 <- lm(mpg ~ log(hp) + log(wt) + qsec, data=mtcars)
scope=list(lower=~1, upper=~log(hp)*log(wt)*qsec)
stepCriterion(fit2, direction="backward", criterion="bic", scope=scope)
stepCriterion(fit2, direction="forward", criterion="cp", scope=scope)
```

```
stepCriterion(fit2, direction="backward", criterion="prdr2", scope=scope)

###### Example 3: Credit card balance
Credit <- ISLR::Credit
fit3 <- lm(Balance ~ Cards + Age + Rating + Income + Student + Limit, data=Credit)
stepCriterion(fit3, direction="forward", criterion="prdr2")
stepCriterion(fit3, direction="forward", criterion="cp")
stepCriterion(fit3, direction="forward", criterion="p-value")
```

`stepCriterion.overglm` *Variable selection for alternatives to the Poisson and Binomial Regression Models under the presence of Overdispersion*

Description

Performs variable selection using hybrid versions of forward stepwise and backward stepwise by comparing hierarchically builded candidate models using a criterion previously specified such as AIC, BIC or p-value of the significance tests.

Usage

```
## S3 method for class 'overglm'
stepCriterion(
  model,
  criterion = c("bic", "aic", "p-value"),
  test = c("wald", "score", "lr", "gradient"),
  direction = c("forward", "backward"),
  levels = c(0.05, 0.05),
  trace = TRUE,
  scope,
  ...
)
```

Arguments

`model`	an object of the class *overglm*.
`criterion`	an (optional) character string which allows to specify the criterion which should be used to compare the candidate models. The available options are: AIC ("aic"), BIC ("bic"), and p-value of the `test`-type test ("p-value"). By default, `criterion` is set to be "bic".
`test`	an (optional) character string which allows to specify the statistical test which should be used to compare nested models. The available options are: Wald ("wald"), Rao's score ("score"), likelihood-ratio ("lr") and gradient ("gradient") tests. By default, `test` is set to be "wald".

`direction`	an (optional) character string which allows to specify the type of procedure which should be used. The available options are: hybrid backward stepwise ("backward") and hybrid forward stepwise ("forward"). By default, `direction` is set to be "forward".
`levels`	an (optional) two-dimensional vector of values in the interval $(0, 1)$ indicating the levels at which the variables should in and out from the model. This is only appropiate if `criterion`="p-value". By default, `levels` is set to be `c(0.05,0.05)`.
`trace`	an (optional) logical switch indicating if should the stepwise reports be printed. By default, `trace` is set to be TRUE.
`scope`	an (optional) list, containing components `lower` and `upper`, both formula-type objects, indicating the range of models which should be examined in the stepwise search. By default, `lower` is a model with no predictors and `upper` is the linear predictor of the model in `model`.
`...`	further arguments passed to or from other methods. For example, k, that is, the magnitude of the penalty in the AIC, which by default is set to be 2.

Value

A list which contains the following objects:

`initial`	a character string indicating the linear predictor of the "initial model",
`direction`	a character string indicating the type of procedure which was used,
`criterion`	a character string indicating the criterion used to compare the candidate models,
`final`	a character string indicating the linear predictor of the "final model",

References

James G., Witten D., Hastie T. and Tibshirani R. (2013, page 210) An Introduction to Statistical Learning with Applications in R. Springer, New York.

See Also

stepCriterion.lm, stepCriterion.glm, stepCriterion.glmgee

Examples

```
###### Example 1: Self diagnozed ear infections in swimmers
fit1 <- overglm(infections ~ age + gender + frequency + location, family="nb1(log)", data=swimmers)

stepCriterion(fit1, criterion="p-value", direction="forward", test="lr")

stepCriterion(fit1, criterion="bic", direction="backward", test="score")

###### Example 2: Article production by graduate students in biochemistry PhD programs
```

```
bioChemists <- pscl::bioChemists
fit2 <- overglm(art ~ fem + mar + kid5 + phd + ment, family="nb1(log)", data = bioChemists)

stepCriterion(fit2, criterion="p-value", direction="forward", test="lr")

stepCriterion(fit2, criterion="bic", direction="backward", test="score")

###### Example 3: Agents to stimulate cellular differentiation
fit3 <- overglm(cbind(cells,200-cells) ~ tnf + ifn + tnf*ifn, family="bb(logit)", data=cellular)

stepCriterion(fit3, criterion="p-value", direction="backward", test="lr")

stepCriterion(fit3, criterion="bic", direction="forward", test="score")
```

`swimmers` *Self diagnozed ear infections in swimmers*

Description

The data come from the Pilot Surf/Health Study of NSW Water Board performed in 1990 on 287 recruits. The objective of the study was to determine, in particular, whether beach swimmers run a greater risk of contracting ear infections than non-beach swimmers. See Hand et al. (1994. page 266).

Usage

```
data(swimmers)
```

Format

A data frame with 287 rows and 5 variables:

frequency a factor giving the recruit's perception of whether he or she is a frequent swimmer: "frequent" and "occasional".

location a factor giving the recruit's usually chosen swimming location: "beach" and "non-beach".

age a factor giving the recruit's age range: "15-19", "20-24" and "25-29".

gender a factor giving the recruit's gender: "male" and "female".

infections a numeric vector giving the number of self diagnozed ear infections that were reported by the recruit.

References

Hand, D.J. and Daly, F. and Lunn, A.D. and McConway, K.J. and Ostrowsky, E. (1994) *A Handbook of Small Data Sets*, Chapman and Hall, London.

Vanegas, L.H. and Rondon, L.M. (2020) A data transformation to deal with constant under/over-dispersion in binomial and poisson regression models. *Journal of Statistical Computation and Simulation* 90, 1811-1833.

Examples

```
boxplot(infections ~ frequency, data=subset(swimmers,location=="non-beach"),
        at=c(1:2)-0.2, col="yellow", boxwex=0.25, outline=FALSE, xaxt="n")
boxplot(infections ~ frequency, data=subset(swimmers,location=="beach"), add=TRUE,
        at=c(1:2)+0.2, col="blue", boxwex=0.25, outline=FALSE, xaxt="n")
axis(1, at=1:2, labels=levels(swimmers$frequency))
legend(0.2, 6.3, legend=c("non-beach","beach"), fill=c("yellow","blue"),
        bty="n", cex=0.7, x.intersp=0.2, y.intersp=1)
```

Trajan *Roots Produced by the Columnar Apple Cultivar Trajan.*

Description

The data arose from a horticultural experiment to study the number of roots produced by 270 micropropagated shoots of the columnar apple cultivar Trajan. During the rooting period, all shoots were maintained under identical conditions, but the shoots themselves were cultured on media containing different concentrations of the cytokinin 6-benzylaminopurine (BAP), in growth cabinets with an 8 or 16 hour photoperiod. The objective is to assess the effect of both the photoperiod and the concentration levels of BAP on the number of roots produced.

Usage

```
data(Trajan)
```

Format

A data frame with 270 rows and 4 variables:

roots a numeric vector indicating the number of roots produced.

shoot a numeric vector indicating the number of micropropogated shoots.

photoperiod a factor indicating the photoperiod, in hours: 8 or 16.

bap a numeric vector indicating the concentrations of the cytokinin 6-benzylaminopurine: 2.2, 4.4, 8.8 or 17.6.

Source

https://support.sas.com/rnd/app/stat/examples/GENMODZIP/sas.html

References

Ridout, M. and Demétrio, C.G. and Hinde, J. (1998). Models for count data with many zeros. In *Proceedings of the XIXth international biometric conference*, 179–192.

Ridout, M. and Hinde, J. and Demétrio, C.G. (2001). A score test for testing a zero-inflated Poisson regression model against zero-inflated negative binomial alternatives. *Biometrics*, 57, 219-223.

Garay, A.M. and Hashimoto, E.M. and Ortega, E.M.M. and Lachos, V. (2011). On estimation and influence diagnostics for zero-inflated negative binomial regression models. *Computational Statistics & Data Analysis* 55, 1304-1318.

Examples

```
boxplot(roots ~ bap, data=subset(Trajan,photoperiod=="8"), at=c(1:4) - 0.15,
    col="blue", boxwex=0.2, outline=FALSE, xaxt="n", xlim=c(0.7,4.3), ylim=c(-0.5,17))
boxplot(roots ~ bap, data=subset(Trajan,photoperiod=="16"), add=TRUE, at=c(1:4) + 0.15,
    col="yellow", boxwex=0.2, outline=FALSE, xaxt="n")
axis(1, at=1:4, labels=levels(Trajan$bap))
legend(0, 18, legend=c("8","16"), title="Photoperiod", bty="n", ncol=1,
    fill=c("blue","yellow"), cex=0.6, x.intersp=0.2, y.intersp=1)
```

---

uti *Urinary Tract Infections in HIV-infected Men*

Description

These data arose from a study conducted in the Department of Internal Medicine at the Utrecht University Hospital, the Netherlands, where 98 human immunodeficiency virus (HIV)-infected men were followed up to two years. Urinary cultures were obtained during the first visit and every six months thereafter. Also, cultures were obtained between regular scheduled visits when signs and symptoms of urinary tract infections (UTI) occurred, or when patients had fever of unknown origin. CD4+ cell counts were also measured. A CD4+ count is a blood test to determine how well the immune system is working in people who have been diagnosed with HIV. In general, a decreasing CD4+ count is an indication of the progression of HIV. See Hoepelman et al. (1992), van den Broek (1995), Morel and Nagaraj (2012, page 175).

Usage

```
data(uti)
```

Format

A data frame with 98 rows and 3 variables:

episodes a numeric vector indicating the number of episodes, that is, the number of times each patient had urinary tract infections (UTI).

time a numeric vector indicating the time to follow up, in months.

cd4 a numeric vector indicating the immune status of the patient as measured by the CD4+ cell counts.

References

Hoepelman, A.I.M. and Van Buren, M. and Van den Broek, J., and Borleffs, J.C.C. (1992) Bacteriuria in men infected with HIV-1 is related to their immune status (CD4+ cell count). *AIDS* 6, 179-184.

Morel, J.G. and Nagaraj, N.K. (2012) *Overdispersion Models in SAS*. SAS Institute Inc., Cary, North Carolina, USA.

van den Broek, J. (1995) A Score Test for Zero Inflation in a Poisson Distribution. *Biometrics* 51, 738–743.

Examples

```
uti2 <- within(uti,cd4C <- cut(log(cd4),4,labels=c("Low","Mid-Low","Mid-High","High")))
out <- aggregate(cbind(episodes,time) ~ cd4C, sum, data=uti2)
barplot(12*episodes/time ~ cd4C, beside=TRUE, data=out, col="red",
        xlab="CD4+ cell count", ylab="Number of UTIs per year")
```

`vcov.glmgee` *Estimate of the variance-covariance matrix in GEEs*

Description

Computes the type-type estimate of the variance-covariance matrix from an object of the class glmgee.

Usage

```
## S3 method for class 'glmgee'
vcov(
  object,
  ...,
  type = c("robust", "df-adjusted", "model", "bias-corrected", "jackknife")
)
```

Arguments

`object`	An object of the class *glmgee*.
`...`	further arguments passed to or from other methods.
`type`	an (optional) character string indicating the type of estimator which should be used. The available options are: robust sandwich-type estimator ("robust"), degrees-of-freedom-adjusted estimator ("df-adjusted"), bias-corrected estimator ("bias-corrected"), and the model-based or naive estimator ("model"). By default, `type` is set to be "robust".

Value

A `matrix` with the type-type estimate of the variance-covariance matrix.

References

Mancl, L.A. and DeRouen, T.A. (2001) A Covariance Estimator for GEE with Improved Small-Sample Properties. *Biometrics* 57, 126-134.

Examples

```
###### Example 1: Effect of ozone-enriched atmosphere on growth of sitka spruces
mod <- size ~ poly(days,4) + treat
fit1 <- glmgee(mod, id=tree, family=Gamma("log"), data=spruces, corstr="Exchangeable")
vcov(fit1)
vcov(fit1,type="bias-corrected")

###### Example 2: Treatment for severe postnatal depression
mod <- depressd ~ visit + group
fit3 <- glmgee(mod, id=subj, family=binomial("logit"), corstr="AR-1", data=depression)
vcov(fit3)
vcov(fit3,type="bias-corrected")

###### Example 3: Treatment for severe postnatal depression (2)
mod <- dep ~ visit*group
fit2 <- glmgee(mod, id=subj, family=gaussian("identity"), corstr="AR-1", data=depression)
vcov(fit2)
vcov(fit2,type="bias-corrected")
```

---

vdtest *Test for Varying Dispersion Parameter*

Description

Generic function for testing for varying dispersion parameter from a fitted model.

Usage

```
vdtest(model, ...)
```

Arguments

`model`	a fitted model object.
`...`	further arguments passed to or from other methods.

Value

A list which includes the main attributes of the test as, for example, value of the statistic and p-value.

vdtest.glm *Test for Varying Dispersion Parameter in Generalized Linear Models*

Description

Performs Rao's score test for varying dispersion parameter in weighted and unweighted generalized linear models in which the response distribution is assumed to be gaussian, Gamma or inverse gaussian.

Usage

```
## S3 method for class 'glm'
vdtest(model, varformula, verbose = TRUE, ...)
```

Arguments

model	an object of the class *glm* where the distribution of the response variable is assumed to be gaussian, Gamma or inverse.gaussian.
varformula	an (optional) formula expression of the form ~ z1 + z2 + ... + zq describing only the potential explanatory variables for the dispersion. By default, the same explanatory variables are taken as in the model for the mean.
verbose	an (optional) logical switch indicating if should the report of results be printed. By default, verbose is set to be TRUE.
...	further arguments passed to or from other methods.

Details

From the generalized lineal model with varying dispersion in which $\log(\phi) = \gamma_0 + \gamma_1 z_1 + \gamma_2 z_2 + ... + \gamma_q z_q$, where ϕ is the dispersion parameter of the distribution used to describe the response variable, the Rao's score test (denoted here as S) to assess the hypothesis $H_0 : \gamma = 0$ versus $H_1 : \gamma \neq 0$ is computed, where $\gamma = (\gamma_1, \ldots, \gamma_q)$. The corresponding *p*-value is computed from the chi-squared distribution with q degrees of freedom, that is, *p*-value = Prob$[\chi^2_q > S]$. If the object model corresponds to an unweighted generalized linear model then this test assess assumptions of constant variance and constant coefficient of variation on models in which the response distribution is assumed to be gaussian and Gamma, respectively.

Value

a list list with components including

statistic	value of the Rao's score test (S),
df	number of degrees of freedom (q),
p.value	*p*-value of the test,

References

Wei, B.-C. and Shi, J.-Q. and Fung, W.-K. and Hu, Y.-Q. (1998) Testing for Varying Dispersion in Exponential Family Nonlinear Models. *Annals of the Institute of Statistical Mathematics* 50, 277–294.

See Also

vdtest.lm

Examples

```
###### Example 1: Fuel consumption of automobiles
Auto <- ISLR::Auto
fit1 <- glm(mpg ~ weight*horsepower, family=inverse.gaussian("log"), data=Auto)
vdtest(fit1)

###### Example 2: Hill races in Scotland
fit2 <- glm(rtime ~ log(distance) + log(cclimb), family=Gamma("log"), data=races)
vdtest(fit2)

###### Example 3: Mammal brain and body weights
fit3 <- glm(BrainWt ~ log(BodyWt), family=Gamma("log"), data=brains)
vdtest(fit3)
```

---

vdtest.lm *Test for Varying Dispersion Parameter in Normal Linear Models*

Description

Performs Rao's score test for varying dispersion parameter in weighted and unweighted normal linear models.

Usage

```
## S3 method for class 'lm'
vdtest(model, varformula, verbose = TRUE, ...)
```

Arguments

`model`	an object of the class *lm*.
`varformula`	an (optional) `formula` expression of the form `~ z1 + z2 + ... + zq` indicating the potential explanatory variables for the dispersion parameter. By default, the same explanatory variables are taken as in the model for the mean.
`verbose`	an (optional) logical switch indicating if should the report of results be printed. By default, `verbose` is set to be TRUE.
`...`	further arguments passed to or from other methods.

Details

From the heteroskedastic normal lineal model in which $\log(\sigma^2) = \gamma_0 + \gamma_1 z_1 + \gamma_2 z_2 + ... + \gamma_q z_q$, where σ^2 is the dispersion parameter of the distribution of the random errors, the Rao's score test (denoted here as S) to assess the hypothesis $H_0 : \gamma = 0$ versus $H_1 : \gamma \neq 0$ is computed, where $\gamma = (\gamma_1, \ldots, \gamma_q)$. The corresponding *p*-value is computed from the chi-squared distribution with q degrees of freedom, that is, *p*-value = Prob$[\chi^2_q > S]$. If the object `model` corresponds to an unweighted normal linear model, then the test assess the assumption of constant variance, which coincides with the non-studentized Breusch-Pagan test against heteroskedasticity.

Value

a list list with components including

`statistic`	value of the Rao's score test (S),
`df`	number of degrees of freedom (q),
`p.value`	*p*-value of the test,

References

Breusch, T.S. and Pagan, A.R. (1979) A simple test for heteroscedasticity and random coefficient variation. *Econometrica* 47, 1287–1294.

Cook, R.D. and Weisberg, S. (1983) Diagnostics for heteroscedasticity in regression. *Biometrika* 70, 1–10.

See Also

vdtest.glm

Examples

```
###### Example 1: Fuel consumption of automobiles
fit1 <- lm(mpg ~ log(hp) + log(wt), data=mtcars)
vdtest(fit1)

###### Example 2: Species richness in plots
fit2 <- lm(Species ~ Biomass + pH, data=richness)
vdtest(fit2)

### The test conclusions change when the outlying observations are excluded
fit2a <- lm(Species ~ Biomass + pH, data=richness, subset=-c(1,3,18,20))
vdtest(fit2a)

###### Example 3: Gas consumption in a home before and after insulation
whiteside <- MASS::whiteside
fit3 <- lm(Gas ~ Temp + Insul + Temp*Insul, data=whiteside)
vdtest(fit3)
```

```
### The test conclusions change when the outlying observations are excluded
fit3a <- lm(Gas ~ Temp + Insul + Temp*Insul, data=whiteside, subset=-c(8,9,36,46,55))
vdtest(fit3a)
```

`zeroalt` *Zero-Altered Regression Models to deal with Zero-Excess in Count Data*

Description

Allows to fit a zero-altered (Poisson or negative binomial) regression model to deal with zero-excess in count data.

Usage

```
zeroalt(
  formula,
  data,
  subset,
  na.action = na.omit(),
  weights,
  family = "poi(log)",
  zero.link = c("logit", "probit", "cloglog", "cauchit", "log"),
  reltol = 1e-13,
  start = list(counts = NULL, zeros = NULL),
  ...
)
```

Arguments

`formula`	a `Formula` expression of the form `response ~ x1 + x2 + ... | z1 + z2 + ...`, which is a symbolic description of the linear predictors of the models to be fitted to μ and π, respectively. See Formula documentation. If a formula of the form `response ~ x1 + x2 + ...` is supplied, then the same regressors are employed in both components. This is equivalent to `response ~ x1 + x2 + ... | x1 + x2 + ...`.
`data`	an (optional) `data frame` in which to look for variables involved in the `formula` expression, as well as for variables specified in the arguments `weights` and `subset`.
`subset`	an (optional) vector specifying a subset of observations to be used in the fitting process.
`na.action`	a function which indicates what should happen when the data contain NAs. By default `na.action` is set to be `na.omit()`.
`weights`	an (optional) vector of positive "prior weights" to be used in the fitting process. The length of `weights` should be the same as the number of observations. By default, `weights` is set to be a vector of 1s.

`family` an (optional) character string which allows to specify the distribution to describe the response variable, as well as the link function to be used in the model for μ. The following distributions are supported: (zero-altered) negative binomial I ("nb1"), (zero-altered) negative binomial II ("nb2"), (zero-altered) negative binomial ("nbf"), and (zero-altered) poisson ("poi"). Link functions available are the same than those available in Poisson models via glm. See family documentation. By default, `family` is set to be Poisson with log link.

`zero.link` an (optional) character string which allows to specify the link function to be used in the model for π. Link functions available are the same than those available in binomial models via glm. See family documentation. By default, `zero.link` is set to be "logit".

`reltol` an (optional) positive value which represents the *relative convergence tolerance* for the BFGS method in optim. By default, `reltol` is set to be 1e-13.

`start` an (optional) list with two components named "counts" and "zeros", which allows to specify the starting values to be used in the iterative process to obtain the estimates of the parameters in the linear predictors of the models for μ and π, respectively.

`...` further arguments passed to or from other methods.

Details

The zero-altered count distributions, also called *hurdle models*, may be obtained as the mixture between a zero-truncated count distribution and the Bernoulli distribution. Indeed, if Y is a count random variable such that $Y|\nu = 1$ is 0 with probability 1 and $Y|\nu = 0$ ~ ZTP(μ), where ν ~ Bernoulli(π), then Y is distributed according to the Zero-Altered Poisson distribution, denoted here as ZAP(μ, π).

Similarly, if Y is a count random variable such that $Y|\nu = 1$ is 0 with probability 1 and $Y|\nu = 0$ ~ ZTNB(μ, ϕ, τ), where ν ~ Bernoulli(π), then Y is distributed according to the Zero-Altered Negative Binomial distribution, denoted here as ZANB(μ, ϕ, τ, π). The Zero-Altered Negative Binomial I (μ, ϕ, π) and Zero-Altered Negative Binomial II (μ, ϕ, π) distributions are special cases of ZANB when $\tau = 0$ and $\tau = -1$, respectively.

The "counts" model may be expressed as $g(\mu_i) = x_i^\top \beta$ for $i = 1, \ldots, n$, where $g(\cdot)$ is the link function specified at the argument `family`. Similarly, the "zeros" model may be expressed as $h(\pi_i) = z_i^\top \gamma$ for $i = 1, \ldots, n$, where $h(\cdot)$ is the link function specified at the argument `zero.link`. The parameter estimation is performed by using the maximum likelihood method. The parameter vector γ is estimated by using the routine glm.fit, where a binary-response model (1 or "success" if `response`=0 and 0 or "fail" if `response`>0) is fitted. Then, the rest of the model parameters are estimated by maximizing the log-likelihood function based on the zero-truncated count distribution using the BFGS method available in the routine optim. The accuracy and speed of the BFGS method are increased because of the call to the routine optim is performed using the analytical instead of the numerical derivatives. The estimate of the variance-covariance matrix is obtained as being minus the inverse of the (analytical) hessian matrix evaluated at the parameter estimates and the observed data.

A set of standard extractor functions for fitted model objects is available for objects of class *zeroinflation*, including methods to the generic functions such as print, summary, model.matrix, estequa, coef, vcov, logLik, fitted, confint, AIC, BIC and predict. In addition, the model fitted to the data may

be assessed using functions such as anova.zeroinflation, residuals.zeroinflation, dfbeta.zeroinflation, cooks.distance.zeroinflation and envelope.zeroinflation.

Value

An object of class *zeroinflation* in which the main results of the model fitted to the data are stored, i.e., a list with components including

`coefficients`	a list with elements "counts" and "zeros" containing the parameter estimates from the respective models,
`fitted.values`	a list with elements "counts" and "zeros" containing the estimates of $\mu_1, \ldots, \mu_n$ and $\pi_1, \ldots, \pi_n$, respectively,
`start`	a vector containing the starting values for all parameters in the model,
`prior.weights`	a vector containing the case weights used,
`offset`	a list with elements "counts" and "zeros" containing the offset vectors, if any, from the respective models,
`terms`	a list with elements "counts", "zeros" and "full" containing the terms objects for the respective models,
`loglik`	the value of the log-likelihood function avaliated at the parameter estimates and the observed data,
`estfun`	a list with elements "counts" and "zeros" containing the estimating functions evaluated at the parameter estimates and the observed data for the respective models,
`formula`	the formula,
`levels`	the levels of the categorical regressors,
`contrasts`	a list with elements "counts" and "zeros" containing the contrasts corresponding to levels from the respective models,
`converged`	a logical indicating successful convergence,
`model`	the full model frame,
`y`	the response count vector,
`family`	a list with elements "counts" and "zeros" containing the family objects used in the respective models,
`linear.predictors`	a list with elements "counts" and "zeros" containing the estimates of $g(\mu_1), \ldots, g(\mu_n)$ and $h(\pi_1), \ldots, h(\pi_n)$, respectively,

R	a matrix with the Cholesky decomposition of the inverse of the variance-covariance matrix of all parameters in the model,
call	the original function call,

References

Cameron, A.C. and Trivedi, P.K. 1998. *Regression Analysis of Count Data*. New York: Cambridge University Press.

Mullahy, J. 1986. Specification and Testing of Some Modified Count Data Models. *Journal of Econometrics* 33, 341–365.

See Also

overglm, zeroinf

Examples

```
####### Example 1: Roots Produced by the Columnar Apple Cultivar Trajan
fit1 <- zeroalt(roots ~ photoperiod, family="nbf(log)", zero.link="logit", data=Trajan)
summary(fit1)

####### Example 2: Self diagnozed ear infections in swimmers
fit2 <- zeroalt(infections ~ frequency | location, family="nb1(log)", data=swimmers)
summary(fit2)

####### Example 3: Article production by graduate students in biochemistry PhD programs
bioChemists <- pscl::bioChemists
fit3 <- zeroalt(art ~ fem + kid5 + ment, family="nb1(log)", data = bioChemists)
summary(fit3)
```

---

zeroinf — *Zero-Inflated Regression Models to deal with Zero-Excess in Count Data*

Description

Allows to fit a zero-inflated (Poisson or negative binomial) regression model to deal with zero-excess in count data.

Usage

```
zeroinf(
  formula,
  data,
  subset,
```

```
  na.action = na.omit(),
  weights,
  family = "poi(log)",
  zero.link = c("logit", "probit", "cloglog", "cauchit", "log"),
  reltol = 1e-13,
  start = list(counts = NULL, zeros = NULL),
  ...
)
```

Arguments

formula	a Formula expression of the form response ~ x1 + x2 + ... | z1 + z2 + ..., which is a symbolic description of the linear predictors of the models to be fitted to μ and π, respectively. See Formula documentation. If a formula of the form response ~ x1 + x2 + ... is supplied, then the same regressors are employed in both components. This is equivalent to response ~ x1 + x2 + ... | x1 + x2 + ...
data	an (optional) data frame in which to look for variables involved in the formula expression, as well as for variables specified in the arguments weights and subset.
subset	an (optional) vector specifying a subset of observations to be used in the fitting process.
na.action	a function which indicates what should happen when the data contain NAs. By default na.action is set to be na.omit().
weights	an (optional) vector of positive "prior weights" to be used in the fitting process. The length of weights should be the same as the number of observations. By default, weights is set to be a vector of 1s.
family	an (optional) character string which allows to specify the distribution to describe the response variable, as well as the link function to be used in the model for μ. The following distributions are supported: (zero-inflated) negative binomial I ("nb1"), (zero-inflated) negative binomial II ("nb2"), (zero-inflated) negative binomial ("nbf"), and (zero-inflated) poisson ("poi"). Link functions available are the same than those available in Poisson models via glm. See family documentation. By default, family is set to be Poisson with log link.
zero.link	an (optional) character string which allows to specify the link function to be used in the model for π. Link functions available are the same than those available in binomial models via glm. See family documentation. By default, zero.link is set to be "logit".
reltol	an (optional) positive value which represents the *relative convergence tolerance* for the BFGS method in optim. By default, reltol is set to be 1e-13.
start	an (optional) list with two components named "counts" and "zeros", which allows to specify the starting values to be used in the iterative process to obtain the estimates of the parameters in the linear predictors to the models for μ and π, respectively.
...	further arguments passed to or from other methods.

Details

The zero-inflated count distributions may be obtained as the mixture between a count distribution and the Bernoulli distribution. Indeed, if Y is a count random variable such that $Y|\nu = 1$ is 0 with probability 1 and $Y|\nu = 0$ ~ Poisson(μ), where ν ~ Bernoulli(π), then Y is distributed according to the Zero-Inflated Poisson distribution, denoted here as ZIP(μ, π).

Similarly, if Y is a count random variable such that $Y|\nu = 1$ is 0 with probability 1 and $Y|\nu = 0$ ~ NB(μ, ϕ, τ), where ν ~ Bernoulli(π), then Y is distributed according to the Zero-Inflated Negative Binomial distribution, denoted here as ZINB(μ, ϕ, τ, π). The Zero-Inflated Negative Binomial I (μ, ϕ, π) and Zero-Inflated Negative Binomial II (μ, ϕ, π) distributions are special cases of ZINB when $\tau = 0$ and $\tau = -1$, respectively.

The "counts" model may be expressed as $g(\mu_i) = x_i^\top \beta$ for $i = 1, \ldots, n$, where $g(\cdot)$ is the link function specified at the argument `family`. Similarly, the "zeros" model may be expressed as $h(\pi_i) = z_i^\top \gamma$ for $i = 1, \ldots, n$, where $h(\cdot)$ is the link function specified at the argument `zero.link`. The parameter estimation is performed by using the maximum likelihood method. The model parameters are estimated by maximizing the log-likelihood function using the BFGS method available in the routine optim. The accuracy and speed of the BFGS method are increased because of the analytical instead of the numerical derivatives are used. The estimate of the variance-covariance matrix is obtained as being minus the inverse of the (analytical) hessian matrix evaluated at the parameter estimates and the observed data.

A set of standard extractor functions for fitted model objects is available for objects of class *zeroinflation*, including methods to the generic functions such as print, summary, model.matrix, estequa, coef, vcov, logLik, fitted, confint, AIC, BIC and predict. In addition, the model fitted to the data may be assessed using functions such as anova.zeroinflation, residuals.zeroinflation, dfbeta.zeroinflation, cooks.distance.zeroinflation and envelope.zeroinflation.

Value

An object of class *zeroinflation* in which the main results of the model fitted to the data are stored, i.e., a list with components including

`coefficients`	a list with elements "counts" and "zeros" containing the parameter estimates from the respective models,
`fitted.values`	a list with elements "counts" and "zeros" containing the estimates of $\mu_1, \ldots, \mu_n$ and $\pi_1, \ldots, \pi_n$, respectively,
`start`	a vector containing the starting values for all parameters in the model,
`prior.weights`	a vector containing the case weights used,
`offset`	a list with elements "counts" and "zeros" containing the offset vectors, if any, from the respective models,
`terms`	a list with elements "counts", "zeros" and "full" containing the terms objects for the respective models,
`loglik`	the value of the log-likelihood function avaliated at the parameter estimates and

	the observed data,
`estfun`	a list with elements "counts" and "zeros" containing the estimating functions evaluated at the parameter estimates and the observed data for the respective models,
`formula`	the formula,
`levels`	the levels of the categorical regressors,
`contrasts`	a list with elements "counts" and "zeros" containing the contrasts corresponding to levels from the respective models,
`converged`	a logical indicating successful convergence,
`model`	the full model frame,
`y`	the response count vector,
`family`	a list with elements "counts" and "zeros" containing the family objects used in the respective models,
`linear.predictors`	a list with elements "counts" and "zeros" containing the estimates of $g(\mu_1), \ldots, g(\mu_n)$ and $h(\pi_1), \ldots, h(\pi_n)$, respectively,
`R`	a matrix with the Cholesky decomposition of the inverse of the variance-covariance matrix of all parameters in the model,
`call`	the original function call,

References

Cameron, A.C. and Trivedi, P.K. 1998. *Regression Analysis of Count Data*. New York: Cambridge University Press.

Lambert, D. 1992. Zero-Inflated Poisson Regression, with an Application to Defects in Manufacturing. *Technometrics* 34, 1-14.

Garay, A.M. and Hashimoto, E.M. and Ortega, E.M.M. and Lachos, V. 2011. On estimation and influence diagnostics for zero-inflated negative binomial regression models. *Computational Statistics & Data Analysis* 55, 1304-1318.

See Also

overglm, zeroalt

Examples

```
####### Example 1: Roots Produced by the Columnar Apple Cultivar Trajan
fit1 <- zeroinf(roots ~ photoperiod, family="nbf(log)", zero.link="logit", data=Trajan)
summary(fit1)
```

```
####### Example 2: Self diagnozed ear infections in swimmers
fit2 <- zeroinf(infections ~ frequency | location, family="nb1(log)", data=swimmers)
summary(fit2)

####### Example 3: Article production by graduate students in biochemistry PhD programs
bioChemists <- pscl::bioChemists
fit3 <- zeroinf(art ~ fem + kid5 + ment | ment, family="nb1(log)", data = bioChemists)
summary(fit3)
```

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