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Description Computes regression deletion diagnostics for multivariate linear models and provides some associated diagnostic plots. The diagnostic measures include hat-values (leverages), generalized Cook's distance, and generalized squared 'studentized' residuals. Several types of plots to detect influential observations are provided.

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`mvinfluence-package` *Influence Measures and Diagnostic Plots for Multivariate Linear Models*

Description

Functions in this package compute regression deletion diagnostics for multivariate linear models following methods proposed by Barrett & Ling (1992) and provide some associated diagnostic plots.

Details

The design goal for this package is that, as an extension of standard methods for univariate linear models, you should be able to fit a linear model with a multivariate response,

```
mymlm <- lm( cbind(y1, y2, y3) ~ x1 + x2 + x3, data=mydata)
```

and then get useful diagnostics and plots with

```
influence(mymlm)
hatvalues(mymlm)
influencePlot(mymlm, ...)
```

The diagnostic measures include hat-values (leverages), generalized Cook's distance and generalized squared 'studentized' residuals. Several types of plots to detect influential observations are provided.

In addition, the functions provide diagnostics for deletion of subsets of observations of size `m>1`. This case is theoretically interesting because sometimes pairs (`m=2`) of influential observations can mask each other, sometimes they can have joint influence far exceeding their individual effects, as

well as other interesting phenomena described by Lawrence (1995). Associated methods for the case m>1 are still under development in this package.

The main function in the package is the S3 method, `influence.mlm`, a simple wrapper for `mlm.influence`, which does the actual computations. This design was dictated by that used in the **stats** package, which provides the generic method `influence` and methods `influence.lm` and `influence.glm`. The **car** package extends this to include `influence.lme` for models fit by `lme`.

The following sections describe the notation and measures used in the calculations.

Notation

Let $\mathbf{X}$ be the model matrix in the multivariate linear model, $\mathbf{Y}_{n\times p} = \mathbf{X}_{n\times r}\boldsymbol{\beta}_{r\times p} + \mathbf{E}_{n\times p}$. The usual least squares estimate of $\boldsymbol{\beta}$ is given by $\mathbf{B} = (\mathbf{X}^T\mathbf{X})^{-1}\mathbf{X}^T\mathbf{Y}$.

Then let

- $\mathbf{X}_I$ be the submatrix of $\mathbf{X}$ whose m rows are indexed by I,
- $\mathbf{X}_{(-I)}$ is the complement, the submatrix of $\mathbf{X}$ with the m rows in I deleted,

Matrices $\mathbf{Y}_I$, $\mathbf{Y}_{(-I)}$ are defined similarly.

In the calculation of regression coefficients, $\mathbf{B}_{(-I)} = (\mathbf{X}_{(-I)}^T\mathbf{X}_{(-I)})^{-1}\mathbf{X}_{(-I)}^T\mathbf{Y}_I$ are the estimated coefficients when the cases indexed by I have been removed. The corresponding residuals are $\mathbf{E}_{(-I)} = \mathbf{Y}_{(-I)} - \mathbf{X}_{(-I)}\mathbf{B}_{(-I)}$.

Hat values and Residuals

The influence measures defined by Barrett & Ling (1992) are functions of two matrices $\mathbf{H}_I$ and $\mathbf{Q}_I$ defined as follows:

- For the full data set, the "hat matrix", $\mathbf{H}$, is given by $\mathbf{H} = \mathbf{X}(\mathbf{X}^T\mathbf{X})^{-1}\mathbf{X}^T$,
- $\mathbf{H}_I$ is $m \times m$ the submatrix of $\mathbf{H}$ corresponding to the index set I, $\mathbf{H}_I = \mathbf{X}(\mathbf{X}_I^T\mathbf{X}_I)^{-1}\mathbf{X}^T$,
- $\mathbf{Q}$ is the analog of $\mathbf{H}$ defined for the residual matrix $\mathbf{E}$, that is, $\mathbf{Q} = \mathbf{E}(\mathbf{E}^T\mathbf{E})^{-1}\mathbf{E}^T$, with corresponding submatrix $\mathbf{Q}_I = \mathbf{E}(\mathbf{E}_I^T\mathbf{E}_I)^{-1}\mathbf{E}^T$,

Cook's distance

In these terms, Cook's distance is defined for a univariate response by

$$D_I = (\mathbf{b} - \mathbf{b}_{(-I)})^T(\mathbf{X}^T\mathbf{X})(\mathbf{b} - \mathbf{b}_{(-I)})/ps^2 \ ,$$

a measure of the squared distance between the coefficients $\mathbf{b}$ for the full data set and those $\mathbf{b}_{(-I)}$ obtained when the cases in I are deleted.

In the multivariate case, Cook's distance is obtained by replacing the vector of coefficients $\mathbf{b}$ by $\mathrm{vec}(\mathbf{B})$, the result of stringing out the coefficients for all responses in a single $n \times p$-length vector.

$$D_I = \frac{1}{p}[\mathrm{vec}(\mathbf{B} - \mathbf{B}_{(-I)})]^T(S^{-1} \otimes \mathbf{X}^T\mathbf{X})\mathrm{vec}(\mathbf{B} - \mathbf{B}_{(-I)}) \ ,$$

where $\otimes$ is the Kronecker (direct) product and $\mathbf{S} = \mathbf{E}^T\mathbf{E}/(n-p)$ is the covariance matrix of the residuals.

Leverage and residual components

For a univariate response, and when `m = 1`, Cook's distance can be re-written as a product of leverage and residual components as

$$D_i = \left(\frac{n-p}{p}\right) \frac{h_{ii} q_{ii}}{(1-h_{ii})^2} \ .$$

Then we can define a leverage component L_i and residual component R_i as

$$L_i = \frac{h_{ii}}{1-h_{ii}} \qquad R_i = \frac{q_{ii}}{1-h_{ii}} \ .$$

R_i is the studentized residual, and $D_i \propto L_i \times R_i$.

In the general, multivariate case there are analogous matrix expressions for $\mathbf{L}$ and $\mathbf{R}$. When `m > 1`, the quantities $\mathbf{H}_I$, $\mathbf{Q}_I$, $\mathbf{L}_I$, and $\mathbf{R}_I$ are $m \times m$ matrices. Where scalar quantities are needed, the package functions apply a function, `FUN`, either `det()` or `tr()` to calculate a measure of "size", as in

```
H <- sapply(x$H, FUN)
Q <- sapply(x$Q, FUN)
L <- sapply(x$L, FUN)
R <- sapply(x$R, FUN)
```

Other measures

The `stats-package` provides a collection of other leave-one-out deletion diagnostics that work with multivariate response models.

`rstandard` Standardized residuals, re-scaling the residuals to have unit variance

`rstudent` Studentized residuals, re-scaling the residuals to have leave-one-out variance

`dffits` a scaled measure of the change in the predicted value for the *i*th observation

`covratio` the change in the determinant of the covariance matrix of the estimates by deleting the *i*th observation

Author(s)

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References

Barrett, B. E. and Ling, R. F. (1992). General Classes of Influence Measures for Multivariate Regression. *Journal of the American Statistical Association*, **87**(417), 184-191.

Barrett, B. E. (2003). Understanding Influence in Multivariate Regression. *Communications in Statistics – Theory and Methods*, **32**, 3, 667-680.

A. J. Lawrence (1995). Deletion Influence and Masking in Regression. *Journal of the Royal Statistical Society. Series B (Methodological)* , **57**, 1, 181-189.

See Also

Useful links:

- https://github.com/friendly/mvinfluence
- https://friendly.github.io/mvinfluence/
- Report bugs at https://github.com/friendly/mvinfluence/issues

Examples

```
data(Rohwer, package="heplots")
Rohwer2 <- subset(Rohwer, subset=group==2)
rownames(Rohwer2) <- 1:nrow(Rohwer2)
Rohwer.mod <- lm(cbind(SAT, PPVT, Raven) ~ n+s+ns+na+ss, data=Rohwer2)

influencePlot(Rohwer.mod, id.n = 3)
# LR plot
influencePlot(Rohwer.mod, id.n = 3, type = "LR")
# 'cookd' plot
influencePlot(Rohwer.mod, id.n = 3, type = "cookd")
```

---

as.data.frame.inflmlm *Convert an inflmlm object to a data frame*

Description

This function is used internally in the package to convert the result of `mlm.influence()` to a data frame. It is not normally called by the user.

Usage

```
## S3 method for class 'inflmlm'
as.data.frame(x, ..., FUN = det, funnames = TRUE)
```

Arguments

`x`	An `inflmlm` object, as returned by `mlm.influence`
`...`	ignored
`FUN`	in the case where the subset size, `m>1`, the function used on the `H`, `Q`, `L`, `R` to calculate a single statistic. The default is `det`. An alternative is `tr`, for matrix trace.
`funnames`	logical. Should the `FUN` name be prepended to the statistics when creating a data frame?

Value

A data frame containing the influence statistics

Examples

```
# none
```

`cooks.distance.mlm` *Cook's distance for a MLM*

Description

The functions `cooks.distance.mlm` and `hatvalues.mlm` are designed as extractor functions for regression deletion diagnostics for multivariate linear models following Barrett & Ling (1992). These are close analogs of methods for univariate and generalized linear models handled by the `influence.measures` in the `stats` package.

Usage

```
## S3 method for class 'mlm'
cooks.distance(model, infl = mlm.influence(model, do.coef = FALSE), ...)
```

Arguments

`model`	A `mlm` object, fit by `lm()`
`infl`	A `inflmlm` object. The default simply runs `mlm.influence()` on the model, suppressing coefficients.
`...`	Ignored

Details

In addition, the functions provide diagnostics for deletion of subsets of observations of size `m>1`.

Value

A vector of Cook's distances

References

Barrett, B. E. and Ling, R. F. (1992). General Classes of Influence Measures for Multivariate Regression. *Journal of the American Statistical Association*, **87**(417), 184-191.

Examples

```
data(Rohwer, package="heplots")
Rohwer2 <- subset(Rohwer, subset=group==2)
rownames(Rohwer2)<- 1:nrow(Rohwer2)
Rohwer.mod <- lm(cbind(SAT, PPVT, Raven) ~ n+s+ns+na+ss, data=Rohwer2)

hatvalues(Rohwer.mod)
cooks.distance(Rohwer.mod)
```

Fertilizer *Fertilizer Data*

Description

A small data set on the use of fertilizer (x) in relation to the amount of grain (y1) and straw (y2) produced.

Format

A data frame with 8 observations on the following 3 variables.

grain amount of grain produced

straw amount of straw produced

fertilizer amount of fertilizer applied

Details

The first observation is an obvious outlier and influential observation.

Source

Anderson, T. W. (1984). *An Introduction to Multivariate Statistical Analysis*, New York: Wiley, p. 369.

References

Hossain, A. and Naik, D. N. (1989). Detection of influential observations in multivariate regression. *Journal of Applied Statistics*, 16 (1), 25-37.

Examples

```
data(Fertilizer)

# simple plots
plot(Fertilizer, col=c('red', rep("blue",7)),
     cex=c(2,rep(1.2,7)),
     pch=as.character(1:8))

# A biplot shows the data in 2D. It gives another view of how case 1 stands out in data space
biplot(prcomp(Fertilizer))

# fit the mlm
mod <- lm(cbind(grain, straw) ~ fertilizer, data=Fertilizer)
Anova(mod)

# influence plots (m=1)
influencePlot(mod)
influencePlot(mod, type='LR')
```

```
influencePlot(mod, type='stres')
```

`hatvalues.mlm` *Hatvalues for a MLM*

Description

The functions `cooks.distance.mlm` and `hatvalues.mlm` are designed as extractor functions for regression deletion diagnostics for multivariate linear models following Barrett & Ling (1992). These are close analogs of methods for univariate and generalized linear models handled by the `influence.measures` in the `stats` package.

Usage

```
## S3 method for class 'mlm'
hatvalues(model, m = 1, infl, ...)
```

Arguments

`model`	An object of class `mlm`, as returned by `lm`
`m`	The size of subsets to be considered
`infl`	An `inflmlm` object, as returned by `mlm.influence`
`...`	Other arguments, for compatibility with the generic; ignored.

Details

Hat values are a component of influence diagnostics, measuring the leverage or outlyingness of observations in the space of the predictor variables.

The usual case considers observations one at a time (`m=1`), where the hatvalue is proportional to the squared Mahalanobis distance, D^2 of each observation from the centroid of all observations. This function extends that definition to calculate a comparable quantity for subsets of size `m>1`.

Value

A vector of hatvalues

References

Barrett, B. E. and Ling, R. F. (1992). General Classes of Influence Measures for Multivariate Regression. *Journal of the American Statistical Association*, **87**(417), 184-191.

See Also

`cooks.distance.mlm`

Examples

```
data(Rohwer, package="heplots")
Rohwer2 <- subset(Rohwer, subset=group==2)
rownames(Rohwer2)<- 1:nrow(Rohwer2)
Rohwer.mod <- lm(cbind(SAT, PPVT, Raven) ~ n+s+ns+na+ss, data=Rohwer2)

options(digits=3)
hatvalues(Rohwer.mod)
cooks.distance(Rohwer.mod)
```

`infIndexPlot.mlm` *Influence Index Plots for Multivariate Linear Models*

Description

Provides index plots of some diagnostic measures for a multivariate linear model: Cook's distance, a generalized (squared) studentized residual, hat-values (leverages), and Mahalanobis squared distances of the residuals.

Usage

```
## S3 method for class 'mlm'
infIndexPlot(
  model,
  infl = mlm.influence(model, do.coef = FALSE),
  FUN = det,
  vars = c("Cook", "Studentized", "hat", "DSQ"),
  main = paste("Diagnostic Plots for", deparse(substitute(model))),
  pch = 19,
  labels,
  id.method = "y",
  id.n = if (id.method[1] == "identify") Inf else 0,
  id.cex = 1,
  id.col = palette()[1],
  id.location = "lr",
  grid = TRUE,
  ...
)
```

Arguments

`model`	A multivariate linear model object of class `mlm` .
`infl`	influence measure structure as returned by `mlm.influence`
`FUN`	For `m>1`, the function to be applied to the H and Q matrices returning a scalar value. `FUN=det` and `FUN=tr` are possible choices, returning the $\|H\|$ and $tr(H)$ respectively.

vars	All the quantities listed in this argument are plotted. Use "Cook" for generalized Cook's distances, "Studentized" for generalized Studentized residuals, "hat" for hat-values (or leverages), and DSQ for the squared Mahalanobis distances of the model residuals. Capitalization is optional. All may be abbreviated by the first one or more letters.
main	main title for graph
pch	Plotting character for points
id.method, labels, id.n, id.cex, id.col, id.location	Arguments for the labeling of points. The default is id.n=0 for labeling no points. See showLabels for details of these arguments.
grid	If TRUE, the default, a light-gray background grid is put on the graph
...	Arguments passed to plot

Details

This function produces index plots of the various influence measures calculated by influence.mlm, and in addition, the measure based on the Mahalanobis squared distances of the residuals from the origin.

Value

None. Used for its side effect of producing a graph.

Author(s)

Michael Friendly; borrows code from car::infIndexPlot

References

Barrett, B. E. and Ling, R. F. (1992). General Classes of Influence Measures for Multivariate Regression. *Journal of the American Statistical Association*, **87**(417), 184-191.

Barrett, B. E. (2003). Understanding Influence in Multivariate Regression *Communications in Statistics - Theory and Methods*, **32**, 667-680.

See Also

influencePlot.mlm, Mahalanobis, infIndexPlot,

Examples

```
# iris data
data(iris)
iris.mod <- lm(as.matrix(iris[,1:4]) ~ Species, data=iris)
infIndexPlot(iris.mod, col=iris$Species, id.n=3)

# Sake data
data(Sake, package="heplots")
Sake.mod <- lm(cbind(taste,smell) ~ ., data=Sake)
infIndexPlot(Sake.mod, id.n=3)
```

```
# Rohwer data
data(Rohwer, package="heplots")
Rohwer2 <- subset(Rohwer, subset=group==2)
rownames(Rohwer2)<- 1:nrow(Rohwer2)
rohwer.mlm <- lm(cbind(SAT, PPVT, Raven) ~ n + s + ns + na + ss, data=Rohwer2)
infIndexPlot(rohwer.mlm, id.n=3)
```

`influence.mlm` *Regression Deletion Diagnostics for Multivariate Linear Models*

Description

This collection of functions is designed to compute regression deletion diagnostics for multivariate linear models following Barrett & Ling (1992) that are close analogs of methods for univariate and generalized linear models handled by the `influence.measures` in the **stats** package.

Usage

```
## S3 method for class 'mlm'
influence(model, do.coef = TRUE, m = 1, ...)
```

Arguments

`model`	An `mlm` object, as returned by `lm`
`do.coef`	logical. Should the coefficients be returned in the `inflmlm` object?
`m`	Size of the subsets for deletion diagnostics
`...`	Other arguments passed to methods

Details

In addition, the functions provide diagnostics for deletion of subsets of observations of size `m>1`.

`influence.mlm` is a simple wrapper for the computational function, `mlm.influence` designed to provide an S3 method for class `"mlm"` objects.

There are still infelicities in the methods for the `m>1` case in the current implementation. In particular, for `m>1`, you must call `influence.mlm` directly, rather than using the S3 generic `influence()`.

Value

`influence.mlm` returns an S3 object of class `inflmlm`, a list with the following components

`m`	Deletion subset size
`H`	Hat values, H_I. If `m=1`, a vector of diagonal entries of the 'hat' matrix. Otherwise, a list of $m \times m$ matrices corresponding to the `subsets`.

Q	Residuals, Q_I.
CookD	Cook's distance values
L	Leverage components
R	Residual components
subsets	Indices of the observations in the subsets of size m
labels	Observation labels
call	Model call for the mlm object
Beta	Deletion regression coefficients– included ifdo.coef=TRUE

Author(s)

Michael Friendly

References

Barrett, B. E. and Ling, R. F. (1992). General Classes of Influence Measures for Multivariate Regression. *Journal of the American Statistical Association*, **87**(417), 184-191.

See Also

influencePlot.mlm, mlm.influence

Examples

```
# Rohwer data
data(Rohwer, package="heplots")
Rohwer2 <- subset(Rohwer, subset=group==2)
rownames(Rohwer2)<- 1:nrow(Rohwer2)
Rohwer.mod <- lm(cbind(SAT, PPVT, Raven) ~ n+s+ns+na+ss, data=Rohwer2)

# m=1 diagnostics
influence(Rohwer.mod) |> head()

# try an m=2 case
## res2 <- influence.mlm(Rohwer.mod, m=2, do.coef=FALSE)
## res2.df <- as.data.frame(res2)
## head(res2.df)
## scatterplotMatrix(log(res2.df))


influencePlot(Rohwer.mod, id.n=4, type="cookd")


# Sake data
data(Sake, package="heplots")
Sake.mod <- lm(cbind(taste,smell) ~ ., data=Sake)
influence(Sake.mod)
influencePlot(Sake.mod, id.n=3, type="cookd")
```

`influencePlot.mlm` *Influence Plots for Multivariate Linear Models*

Description

This function creates various types of "bubble" plots of influence measures with the areas of the circles representing the observations proportional to generalized Cook's distances.

Usage

```
## S3 method for class 'mlm'
influencePlot(
  model,
  scale = 12,
  type = c("stres", "LR", "cookd"),
  infl = mlm.influence(model, do.coef = FALSE),
  FUN = det,
  fill = TRUE,
  fill.col = "red",
  fill.alpha.max = 0.5,
  labels,
  id.method = "noteworthy",
  id.n = if (id.method[1] == "identify") Inf else 0,
  id.cex = 1,
  id.col = palette()[1],
  ref.col = "gray",
  ref.lty = 2,
  ref.lab = TRUE,
  ...
)
```

Arguments

`model`	An `mlm` object, as returned by `lm` with a multivariate response.
`scale`	a factor to adjust the radii of the circles, in relation to `sqrt(CookD)`
`type`	Type of plot: one of `c("stres", "cookd", "LR")`. See Details.
`infl`	influence measure structure as returned by `mlm.influence`
`FUN`	For `m>1`, the function to be applied to the H and Q matrices returning a scalar value. `FUN=det` and `FUN=tr` are possible choices, returning the $\|H\|$ and $tr(H)$ respectively.
`fill, fill.col, fill.alpha.max`	`fill`: logical, specifying whether the circles should be filled. When `fill=TRUE`, `fill.col` gives the base fill color to which transparency specified by `fill.alpha.max` is applied.

`labels`, `id.method`, `id.n`, `id.cex`, `id.col`
: settings for labeling points; see `showLabels` for details. To omit point labeling, set `id.n=0`, the default. The default `id.method="noteworthy"` is used in this function to indicate setting labels for points with large Studentized residuals, hat-values or Cook's distances. See Details below. Set `id.method="identify"` for interactive point identification.

`ref.col`, `ref.lty`, `ref.lab`
: arguments for reference lines. Incompletely implemented in this version

`...`
: other arguments passed down

Details

`type="stres"` plots squared (internally) Studentized residuals against hat values; `type="cookd"` plots Cook's distance against hat values; `type="LR"` plots residual components against leverage components, with the attractive property that contours of constant Cook's distance fall on diagonal lines with slope = -1. Adjacent reference lines represent multiples of influence.

The `id.method="noteworthy"` setting also requires setting `id.n>0` to have any effect. Using `id.method="noteworthy"`, and `id.n>0`, the number of points labeled is the union of the largest `id.n` values on each of L, R, and CookD.

Value

If points are identified, returns a data frame with the hat values, Studentized residuals and Cook's distance of the identified points. If no points are identified, nothing is returned. This function is primarily used for its side-effect of drawing a plot.

Author(s)

Michael Friendly

References

Barrett, B. E. and Ling, R. F. (1992). General Classes of Influence Measures for Multivariate Regression. *Journal of the American Statistical Association*, **87**(417), 184-191.

Barrett, B. E. (2003). Understanding Influence in Multivariate Regression *Communications in Statistics - Theory and Methods*, **32**, 667-680.

McCulloch, C. E. & Meeter, D. (1983). Discussion of "Outliers..." by R. J. Beckman and R. D. Cook. *Technometrics*, 25, 152-155

See Also

`mlm.influence`, `lrPlot`

`influencePlot` in the car package

Examples

```
data(Rohwer, package="heplots")
Rohwer2 <- subset(Rohwer, subset=group==2)
Rohwer.mod <- lm(cbind(SAT, PPVT, Raven) ~ n+s+ns+na+ss, data=Rohwer2)

# Types of influence plots
influencePlot(Rohwer.mod, id.n=4, type="stres")

influencePlot(Rohwer.mod, id.n=4, type="LR")

influencePlot(Rohwer.mod, id.n=4, type="cookd")

# Sake data
data(Sake, package="heplots")
 Sake.mod <- lm(cbind(taste,smell) ~ ., data=Sake)

 influencePlot(Sake.mod, id.n=3, type="stres")

 influencePlot(Sake.mod, id.n=3, type="LR")

 influencePlot(Sake.mod, id.n=3, type="cookd")

# Adopted data
data(Adopted, package="heplots")
Adopted.mod <- lm(cbind(Age2IQ, Age4IQ, Age8IQ, Age13IQ) ~ AMED + BMIQ, data=Adopted)

influencePlot(Adopted.mod, id.n=3)

influencePlot(Adopted.mod, id.n=3, type="LR", ylim=c(-4,-1.5))

# schooldata
data(schooldata, package = "heplots")
school.mod <- lm(cbind(reading, mathematics, selfesteem) ~ .,
                 data=schooldata)

influencePlot(school.mod, id.n=4, type="stres")

influencePlot(school.mod, id.n=4, type="LR")
```

`Jfuns` *General Classes of Influence Measures*

Description

These functions implement the general classes of influence measures for multivariate regression models defined in Barrett and Ling (1992), Eqn 2.3, 2.4, as shown in their Table 1.

Usage

```
Jtr(H, Q, a, b, f)

Jdet(H, Q, a, b, f)

COOKD(H, Q, n, p, r, m)

DFFITS(H, Q, n, p, r, m)

COVRATIO(H, Q, n, p, r, m)
```

Arguments

H	a scalar or $m \times m$ matrix giving the hat values for subset I
Q	a scalar or $m \times m$ matrix giving the residual values for subset I
a	the a parameter for the J^{det} and J^{tr} classes
b	the b parameter for the J^{det} and J^{tr} classes
f	scaling factor for the J^{det} and J^{tr} classes
n	sample size
p	number of predictor variables
r	number of response variables
m	deletion subset size

Details

There are two classes of functions, denoted J_I^{det} and J_I^{tr}, with parameters n, p, q of the data, m of the subset size and a and b which define powers of terms in the formulas, typically in the set `-2`, `-1`, `0`.

They are defined in terms of the submatrices for a deleted index subset I,

$$H_I = X_I(X^T X)^{-1} X_I$$

$$Q_I = E_I(E^T E)^{-1} E_I$$

corresponding to the hat and residual matrices in univariate models.

For subset size $m = 1$ these evaluate to scalar equivalents of hat values and studentized residuals.

For subset size $m > 1$ these are $m \times m$ matrices and functions in the J^{det} class use $|H_I|$ and $|Q_I|$, while those in the J^{tr} class use $tr(H_I)$ and $tr(Q_I)$.

The functions `COOKD`, `COVRATIO`, and `DFFITS` implement some of the standard influence measures in these terms for the general cases of multivariate linear models and deletion of subsets of size `m>1`, but they have not yet been incorporated into our main functions `mlm.influence` and `influence.mlm`.

Value

The scalar result of the computation.

Author(s)

Michael Friendly

References

Barrett, B. E. and Ling, R. F. (1992). General Classes of Influence Measures for Multivariate Regression. *Journal of the American Statistical Association*, **87**(417), 184-191.

`lrPlot` *Regression LR Influence Plot*

Description

This function creates a "bubble" plot of functions, R = log(Studentized residuals^2) by L = log(H/p*(1-H)) of the hat values, with the areas of the circles representing the observations proportional to Cook's distances.

Usage

```
lrPlot(model, ...)

## S3 method for class 'lm'
lrPlot(
  model,
  scale = 12,
  xlab = "log Leverage factor [log H/p*(1-H)]",
  ylab = "log (Studentized Residual^2)",
  xlim = NULL,
  ylim,
  labels,
  id.method = "noteworthy",
  id.n = if (id.method[1] == "identify") Inf else 0,
  id.cex = 1,
  id.col = palette()[1],
  ref = c("h", "v", "d", "c"),
  ref.col = "gray",
  ref.lty = 2,
  ref.lab = TRUE,
  ...
)
```

Arguments

`model`	a model object fit by `lm`
`...`	arguments to pass to the `plot` and `points` functions.
`scale`	a factor to adjust the radii of the circles, in relation to `sqrt(CookD)`

`xlab`, `ylab` axis labels.

`xlim`, `ylim` Limits for x and y axes. In the space of (L, R) very small residuals typically extend the y axis enough to swamp the large residuals, so the default for `ylim` is set to a range of 6 log units starting at the maximum value.

`labels`, `id.method`, `id.n`, `id.cex`, `id.col`
settings for labeling points; see `link{showLabels}` for details. To omit point labeling, set `id.n=0`, the default. The default `id.method="noteworthy"` is used in this function to indicate setting labels for points with large Studentized residuals, hat-values or Cook's distances. See Details below. Set `id.method="identify"` for interactive point identification.

`ref` Options to draw reference lines, any one or more of `c("h", "v", "d", "c")`. `"h"` and `"v"` draw horizontal and vertical reference lines at noteworthy values of R and L respectively. `"d"` draws equally spaced diagonal reference lines for contours of equal CookD. `"c"` draws diagonal reference lines corresponding to approximate 0.95 and 0.99 contours of CookD.

`ref.col`, `ref.lty`
Color and line type for reference lines. Reference lines for `"c"` `%in%` `ref` are handled separately.

`ref.lab` A logical, indicating whether the reference lines should be labeled.

Details

This plot, suggested by McCulloch & Meeter (1983) has the attractive property that contours of equal Cook's distance are diagonal lines with slope = -1. Various reference lines are drawn on the plot corresponding to twice and three times the average hat value, a "large" squared studentized residual and contours of Cook's distance.

The `id.method="noteworthy"` setting also requires setting `id.n>0` to have any effect. Using `id.method="noteworthy"`, and `id.n>0`, the number of points labeled is the union of the largest `id.n` values on each of L, R, and CookD.

Value

If points are identified, returns a data frame with the hat values, Studentized residuals and Cook's distance of the identified points. If no points are identified, nothing is returned. This function is primarily used for its side-effect of drawing a plot.

Author(s)

Michael Friendly

References

A. J. Lawrence (1995). Deletion Influence and Masking in Regression *Journal of the Royal Statistical Society. Series B (Methodological)* , Vol. **57**, No. 1, pp. 181-189.

McCulloch, C. E. & Meeter, D. (1983). Discussion of "Outliers..." by R. J. Beckman and R. D. Cook. *Technometrics*, 25, 152-155.

See Also

`influencePlot.mlm` `influencePlot` in the `car` package for other methods

Examples

```
# artificial example from Lawrence (1995)
x <- c( 0, 0, 7, 7, 8, 8, 9, 9, 10, 10, 11, 11, 18, 18 )
y <- c( 0, 6, 6, 7, 6, 7, 6, 7, 6,  7,  6,  7,  7,  18 )
DF <- data.frame(x,y, row.names=LETTERS[1:length(x)])
DF

with(DF, {
 plot(x,y, pch=16, cex=1.3)
 abline(lm(y~x), col="red", lwd=2)
 NB <- c(1,2,13,14)
 text(x[NB],y[NB], LETTERS[NB], pos=c(4,4,2,2))
 }
)

mod <- lm(y~x, data=DF)
# standard influence plot from car
influencePlot(mod, id.n=4)

# lrPlot version
lrPlot(mod, id.n=4)


library(car)
dmod <- lm(prestige ~ income + education, data = Duncan)
influencePlot(dmod, id.n=3)
lrPlot(dmod, id.n=3)

# NLSY data
```

`mlm.influence` *Calculate Regression Deletion Diagnostics for Multivariate Linear Models*

Description

`mlm.influence` is the main computational function in this package. It is usually not called directly, but rather via its alias, `influence.mlm`, the S3 method for a `mlm` object.

Usage

```
mlm.influence(model, do.coef = TRUE, m = 1, ...)
```

Arguments

model	An mlm object, as returned by lm with a multivariate response.
do.coef	logical. Should the coefficients be returned in the inflmlm object?
m	Size of the subsets for deletion diagnostics
...	Further arguments passed to other methods

Details

The computations and methods for the m=1 case are straight-forward, as are the computations for the m>1 case. Associated methods for m>1 are still under development.

Value

mlm.influence returns an S3 object of class inflmlm, a list with the following components:

m	Deletion subset size
H	Hat values, H_I. If m=1, a vector of diagonal entries of the 'hat' matrix. Otherwise, a list of $m \times m$ matrices corresponding to the subsets.
Q	Residuals, Q_I.
CookD	Cook's distance values
L	Leverage components
R	Residual components
subsets	Indices of the observations in the subsets of size m
labels	Observation labels
call	Model call for the mlm object
Beta	Deletion regression coefficients– included ifdo.coef=TRUE

Author(s)

Michael Friendly

References

Barrett, B. E. and Ling, R. F. (1992). General Classes of Influence Measures for Multivariate Regression. *Journal of the American Statistical Association*, **87**(417), 184-191.

Barrett, B. E. (2003). Understanding Influence in Multivariate Regression. *Communications in Statistics – Theory and Methods*, **32**, 3, 667-680.

See Also

influencePlot.mlm

Examples

```
data(Rohwer, package = "heplots")
Rohwer2 <- subset(Rohwer, subset=group==2)
rownames(Rohwer2)<- 1:nrow(Rohwer2)
Rohwer.mod <- lm(cbind(SAT, PPVT, Raven) ~ n+s+ns+na+ss, data=Rohwer2)
Rohwer.mod
influence(Rohwer.mod)

# extract the most influential cases
influence(Rohwer.mod) |>
    as.data.frame() |>
    dplyr::arrange(dplyr::desc(CookD)) |>
    head()

# Sake data
data(Sake, package = "heplots")
Sake.mod <- lm(cbind(taste,smell) ~ ., data=Sake)
influence(Sake.mod) |>
    as.data.frame() |>
    dplyr::arrange(dplyr::desc(CookD)) |> head()
```

---

mpower *General Matrix Power*

Description

Calculates the n-th power of a square matrix, where n can be a positive or negative integer or a fractional power.

Usage

```
mpower(A, n)

A %^% n
```

Arguments

A	A square matrix. Must also be symmetric for non-integer powers.
n	matrix power

Details

If n<0, the method is applied to A^{-1}. When n is an integer, the function uses the Russian peasant method, or repeated squaring for efficiency. Otherwise, it uses the spectral decomposition of A, $\mathbf{A}^n = \mathbf{V}\mathbf{D}^n\mathbf{V}^T$ requiring a symmetric matrix.

Value

Returns the matrix A^n

Author(s)

Michael Friendly

References

https://en.wikipedia.org/wiki/Exponentiation_by_squaring

See Also

Packages **corpcor** and **expm** define similar functions.

Examples

```
M <- matrix(sample(1:9), 3,3)
mpower(M,2)
mpower(M,4)

# make a symmetric matrix
MM <- crossprod(M)
mpower(MM, -1)
Mhalf <- mpower(MM, 1/2)
all.equal(MM, Mhalf %*% Mhalf)
```

---

print.inflmlm *Print an inflmlm object*

Description

Print an inflmlm object

Usage

```
## S3 method for class 'inflmlm'
print(x, digits = max(3, getOption("digits") - 4), FUN = det, ...)
```

Arguments

x	An inflmlm object
digits	Number of digits to print
FUN	Function to combine diagnostics when m>1, one of det or tr
...	passed to print()

Value

Invisibly returns the object

Examples

```
# none
```

`tr` *Matrix trace*

Description

Calculates the trace of a matrix

Usage

```
tr(M)
```

Arguments

`M`	a matrix

Details

For square, symmetric matrices, such as covariance matrices, the trace is sometimes used as a measure of size, e.g., in Pillai's trace criterion for a MLM.

Value

returns the sum of the diagonal elements of the matrix

Author(s)

Michael Friendly

Examples

```
M <- matrix(sample(1:9), 3,3)
tr(M)
```

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