

# Package ‘lmreg’

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**Description** Data files and a few functions used in the book  
'Linear Models and Regression with R: An Integrated Approach'  
by Debasis Sengupta and Sreenivas Rao Jammalamadaka (2019).

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airspeed	<i>Air speed experiment data</i>
----------	----------------------------------

---

### Description

Air speed data, which is part of a larger data set from a designed experiment (Wilkie, 1962).

### Usage

`data(airspeed)`

**Format**

A data frame with 18 observations on the following 3 variables.

Posmaxspeed The position of highest speed of air blown down the space between a roughened rod and a smoothed pipe surrounding it. The position is defined as the distance (in inches) from the center of the rod, in excess of 1.4 inches

Reynolds Reynolds number of air flow (dimensionless)

Ribht Height of ribs on the roughened rod (in inches)

**Source**

Wilkie, D. (1962) A method of analysis of mixed level factorial experiments. Applied Statistics, pp.184-195.

**Examples**

```
data(airspeed)
head(airspeed)
```

---

anscombeplus

*Six data sets with similar regression summary*

---

**Description**

Six synthetic data sets with similar regression summary, for illustrating the importance of regression diagnostics.

**Usage**

```
data(anscombeplus)
```

**Format**

A data frame with 20 observations on 8 synthetic real-valued variables, labelled as x1, y1, y2, y3, y4, y5, x2, y6.

x1 Explanatory variable of first five data sets

y1 Response variable of first data set

y2 Response variable of second data set

y3 Response variable of third data set

y4 Response variable of fourth data set

y5 Response variable of fifth data set

x2 Explanatory variable of sixth data set

y6 Response variable of sixth data set

**Details**

This data set is presented by Sengupta and Jammalamadaka (2019), after expanding on the ideas of Anscombe (1973)

**Source**

Anscombe, F.J. (1973), Graphs in statistical analysis, American Statistician, vol.27, pp.17-21.

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach, World Scientific Publishing Co., Table 5.1.

**Examples**

```
data(anscombeplus)
head(anscombeplus)
```

---

appletree

*Apple yield with cropping under tree*

---

**Description**

Apple crop volume under various ground covers underneath tree (Pearce, 1983)

**Usage**

```
data(appletree)
```

**Format**

A data frame with 24 observations on the following 4 variables.

Weight Total weight (in pounds) of apple produced in a plot in four years, post-treatment

Treatment Five types of permanent cropping under the apple tree (coded as 1 to 5), or no cropping at all (0)

Block Blocks coded as 1 to 4

Volume Total crop volume (in bushels) in four years, pre-treatment

**Source**

Pearce, S.C. (1983) The Agricultural Field Experiment, Wiley, Chechester, p.284.

**Examples**

```
data(appletree)
head(appletree)
```

---

basis	<i>Basis of column space of a matrix</i>
-------	--

---

**Description**

Computes an orthonormal basis of the column space of a given matrix.

**Usage**

```
basis(M, tol=sqrt(.Machine$double.eps))
```

**Arguments**

M	Matrix for which basis of the column space is needed.
tol	A relative tolerance to determine rank through qr decomposition (default = sqrt(.Machine\$double.eps)).

**Value**

Returns a semi-orthogonal matrix with columns forming an orthonormal basis of the column space of M.

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
basis(matrix(c(2,1,3,4,2,3,2,6,4,2,6,8),4,3))
```

---

binaries	<i>Convert categorical variable to several binary variables</i>
----------	---

---

**Description**

Stacks up in columns the values of all the binary variables that can be associated with different levels of a categorical variable.

**Usage**

```
binaries(x)
```

**Arguments**

x                    A categorical variable (either numeric or character).

**Details**

The name of each new variable is of the type v.x, where x is the level of the categorical variable for which this binary variable is equal to 1.

**Value**

A set of binary vectors, each having the value 1 for a unique level of x.

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
x <- c(1,2,2,3,1,1,2,3,3,2,1)
binaries(x)
binaries(as.factor(x))
```

---

cisimult

*Simultaneous confidence intervals in a linear model*

---

**Description**

Produces two-sided Bonferroni and Scheffe simultaneous confidence intervals, together with corresponding single confidence intervals, for any vector of estimable functions A.beta in a linear model.

**Usage**

```
cisimult(y, X, A, alpha, tol=sqrt(.Machine$double.eps))
```

**Arguments**

y                    Responese vector in linear model.  
X                    Design/model matrix or matrix containing values of explanatory variables (generally including intercept).  
A                    Coefficient matrix (A.beta is the vector for which confidence interval is needed).  
alpha                Collective non-coverage probability of confidence intervals.  
tol                   A relative tolerance to detect zero singular values while computing generalized inverse, in case X is rank deficient (default = sqrt(.Machine\$double.eps)).

**Details**

Normal distribution of response (given explanatory variables and/or factors) is assumed.

**Value**

The three sets of confidence intervals listed as below:

BFCB	Two-sided Bonferroni simultaneous confidence intervals.
SFCB	Two-sided Scheffe simultaneous confidence intervals.
SNCB	The single confidence intervals.

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
data(denim)
attach(denim)
X <- cbind(1, binaries(Denim), binaries(Laundry))
A <- rbind(c(0,1,-1,0,0,0,0), c(0,1,0,-1,0,0,0), c(0,0,1,-1,0,0,0))
cisimult(Abrasion, X, A, 0.05, tol = 1e-10)
detach(denim)
```

---

cisngl

*Confidence interval for a linear parametric function in a linear model*

---

**Description**

Computes point estimate and confidence interval for a single linear parametric function in a linear model.

**Usage**

```
cisngl(y, X, p, alpha, type, tol=sqrt(.Machine$double.eps))
```

**Arguments**

y	Response vector in linear model.
X	Design/model matrix or matrix containing values of explanatory variables (generally including intercept).
p	Coefficient vector of linear parametric function for which confidence interval is needed.
alpha	Non-coverage probability of confidence interval.
type	Type of confidence interval ("lower", "upper", "both").
tol	A relative tolerance to detect zero singular values while computing generalized inverse, in case X is rank deficient (default = $\sqrt{\text{Machine\$double.eps}}$ ).

**Details**

Normal distribution of response (given explanatory variables and/or factors) is assumed.

**Value**

Returns a list of two objects:

estimate	Point estimate.
ci	Confidence interval.

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
library(MASS)
data(birthwt)
attach(birthwt)
X <- cbind(1, smoke, binaries(race))
p <- c(0,1,0,0,0)
cisngl(bwt, X, p, 0.05, type = "upper", tol = 1e-10)
cisngl(bwt, X, p, 0.05, type = "both", tol = 1e-10)
detach(birthwt)
```



---

`cism`*Table of condition indices and singular vectors*

---

**Description**

Computes the table of condition indices and model matrix singular vectors for a linear model.

**Usage**

```
cism(lmobj)
```

**Arguments**

`lmobj` An object produced by `lm` fitting.

**Details**

Columns containing different elements of a singular vector are labelled either as (Intercept) or by the variable name.

**Value**

Returns the table of condition indices and model matrix right singular vectors for the chosen model, with singular vectors appearing as rows next to the corresponding condition index. Columns containing different elements of a singular vector are labelled either as (Intercept) or by the variable name.

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
data(imf2015)
lmimf <- lm(UNMP~CAB+DEBT+EXP+GDP+INFL+INV, data = imf2015)
cism(lmimf)
```

---

`compbasis`*Basis of orthogonal complement of column space of a matrix*

---

**Description**

Computes an orthonormal basis of the orthogonal complement of the column space of a given matrix.

**Usage**

```
compbasis(M, tol=sqrt(.Machine$double.eps))
```

**Arguments**

<code>M</code>	Matrix for which basis of the orthogonal complement of the column space is needed.
<code>tol</code>	A relative tolerance to determine rank through qr decomposition (default = $\sqrt{\text{.Machine\$double.eps}}$ ).

**Value**

Returns a semi-orthogonal matrix with columns forming an orthonormal basis of the orthogonal complement of the column space of `M`.

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
compbasis(matrix(c(3,3,3,3),2,2))
```

---

`confelps`*Confidence ellipsoid for multiple parameters in a linear model.*

---

**Description**

Computes confidence ellipsoid for a vector of estimable functions in a linear model.

**Usage**

```
confelps(y, X, A, alpha, tol=sqrt(.Machine$double.eps))
```

**Arguments**

<code>y</code>	Response vector in linear model.
<code>X</code>	Design/model matrix or matrix containing values of explanatory variables (generally including intercept).
<code>A</code>	Coefficient matrix ( <code>A.beta</code> is the vector for which confidence interval is needed).
<code>alpha</code>	The non-coverage probability of confidence ellipsoid.
<code>tol</code>	A relative tolerance to detect zero singular values while computing generalized inverse, in case <code>X</code> is rank deficient (default = <code>sqrt(.Machine\$double.eps)</code> ).

**Details**

Normal distribution of response (given explanatory variables and/or factors) is assumed.

**Value**

Returns a list of three objects:

`CenterOfEllipse`

Center of ellipsoid.

`MatrixOfEllipse`

Matrix of ellipsoid, for describing quadratic form in terms of the vector of deviations from center of ellipsoid.

`threshold`

Upper limit of quadratic form that completes specification of ellipsoid.

**Author(s)**

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**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
data(denim)
attach(denim)
X <- cbind(1, binaries(Denim), binaries(Laundry))
A <- rbind(c(0,1,0,-1,0,0,0), c(0,0,1,-1,0,0,0))
confelpls(Abrasion, X, A, 0.05, tol=1e-12)
detach(denim)
```

---

denim

*Abrasion of denim jeans*

---

**Description**

Effects of Laundering Cycles and denim treatment on edge abrasion of denim jeans (Card et al., 2006). Data simulated to match means/SDs.

**Usage**

```
data(denim)
```

**Format**

A data frame with 90 observations on the following 3 variables.

Laundry Three levels of laundry cycles (1 = 0 cycle, 2 = 5 cycles, 3 = 25 cycles)

Denim Three types of denim treatments (1 = pre-washed, 2 = stone-washed, 3 = enzyme washed)

Abrasion abrasion score (lower score means higher damage)

**Source**

Card, A., Moore, M.A. and Ankeny, M. (2006) Garment washed jeans: Impact of launderings on physical properties. *Int. J. Clothing Sc. Tech.*, 18, pp.43-52.

**Examples**

```
data(denim)
head(denim)
```

---

`drugprice`*Price of drugs under generic and brand names*

---

**Description**

Across-countries median of median price ratio (MPR) of some medicines available in the private market under the generic name and the brand name of the originator (Gelders et al., 2005).

**Usage**

```
data(drugprice)
```

**Format**

A data frame with 13 observations on the following 2 variables.

Drug Generic name of drug, a character vector

Quantity Unit for price computation, a character vector

OriginatorMPR Originator median price ratio, a numeric vector

GenericMPR Generic median price ratio, a numeric vector

**Details**

The data comes from a World Health Organization (WHO) commissioned study on variation of drug prices over a number of developing countries. For comparability, the price in a particular region is expressed as a ratio (called median price ratio or MPR) with respect to the organization's drug price indicator median values. The data reflect the across-country median of these ratios in respect of 13 medicines, most of which are in the WHO list of essential medicines.

**Source**

Gelders, S., Ewen, M., Noguchi, N. and Laing R. (2005). Price, Availability and Affordability: An International Comparison of Chronic Disease Medicines, Background report prepared for the WHO Planning Meeting on the Global Initiative for Treatment of Chronic Diseases, Cairo, December 2005.

**Examples**

```
data(drugprice)
head(drugprice)
```

---

frob	<i>Frobenius norm of a matrix</i>
------	-----------------------------------

---

**Description**

Computes the Frobenius norm of a given matrix.

**Usage**

```
frob(M)
```

**Arguments**

M                      Matrix whose Frobenius norm is to be computed.

**Value**

A scalar value, describing the Frobenius norm (positive square root of sum of squared elements) of M.

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
frob(matrix(2,3,2))
```

---

ganova	<i>ANOVA table for linear hypothesis in a linear model</i>
--------	--

---

**Description**

Prepares Analysis of Variance table for testing a general linear hypothesis in a linear model

**Usage**

```
ganova(y, X, A, xi, tol=sqrt(.Machine$double.eps))
```

**Arguments**

y	Response vector in linear model.
X	Design matrix or matrix containing values of explanatory variables (generally including intercept).
A	Coefficient matrix ( $A\beta = \xi$ is the null hypothesis to be tested).
xi	A vector ( $A\beta = \xi$ is the null hypothesis to be tested).
tol	A relative tolerance to detect zero singular values while computing generalized inverse, in case the model matrix is rank deficient (default = $\sqrt{\text{Machine\$double.eps}}$ ).

**Value**

Returns analysis of variance table for testing  $A\beta = \xi$  in the linear model with response vector y and matrix of explanatory variables/factors X.

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
data(denim)
attach(denim)
X <- cbind(1, binaries(Denim), binaries(Laundry))
A <- rbind(c(0,1,-1,0,0,0,0), c(0,1,0,-1,0,0,0))
xi <- c(0, 0)
ganova(Abrasion, X, A, xi)
detach(denim)
```

---

girlgrowth

*Growth data for girls*

---

**Description**

Heights of some adolescent girls, aged 7 to 12, in the southern part of Kolkata, India around the year 2008.

**Usage**

```
data(girlgrowth)
```

**Format**

A data frame with 905 observations on the following 2 variables.

Age Age of girls (in years)

Height Height of girls (in cm)

**Source**

Dasgupta (2015), Physical Growth, Body Composition and Nutritional Status of Bengali School aged Children, Adolescents and Young adults of Calcutta, India: Effects of Socioeconomic Factors on Secular Trends, Report 158, Ney-van Hoogstraten Foundation, The Netherlands.

**Examples**

```
data(girlgrowth)
head(girlgrowth)
```

---

hanova	<i>ANOVA table for adequacy of a subset in a linear model</i>
--------	---

---

**Description**

Prepares the Analysis of Variance table for testing adequacy of a subset model within a linear model.

**Usage**

```
hanova(lm1, lm2)
```

**Arguments**

lm1	An lm object describing full model.
lm2	An lm object describing subset model.

**Details**

Normal distribution of response (given explanatory variables and/or factors) is assumed. The program simply reformats the output of the [anova](#) function.

**Value**

Returns analysis of variance table for testing adequacy of lm2 within lm1.

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>



**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
data(birthwt)
lmbw <- lm(bwt ~ smoke+factor(race), data = birthwt)
lm1 <- lm(bwt ~ smoke, data = birthwt)
hanova(lm1, lmbw)
```

---

hiv

*HIV data*

---

**Description**

Light absorbance for positive control samples in an ELISA test for HIV (Hoaglin et al., 1991).

**Usage**

```
data(hiv)
```

**Format**

A data frame with 75 observations on the following 3 variables.

Absorbance Measurement of absorbance of light (dimensionless)

Lot Five levels of lot

Run Five levels of run

**Source**

Hoaglin, D.C., Mosteller, F. and Tukey, J.W. (1991) Fundamentals of Exploratory Analysis of Variance, Wiley, New York, p.107.

**Examples**

```
data(hiv)
head(hiv)
```

---

hoop	<i>Hoop tree data</i>
------	-----------------------

---

**Description**

Compressive strength and moisture content of wood in hoop trees (Williams, 1959).

**Usage**

```
data(hoop)
```

**Format**

A data frame with 50 observations on the following 4 variables.

Temp Temperature (in Celsius)

Tree Hoop tree number

Strength Maximum compressive strength parallel to the grain (in MPa)

Moisture Moisture content (100 times water mass/dry wood mass)

**Source**

Williams, E.J. (1959) Regression Analysis, Wiley, New York.

**Examples**

```
data(hoop)
head(hoop)
```

---

hypspllit	<i>Testable and untestable hypotheses in linear model</i>
-----------	---

---

**Description**

Reduces a general hypothesis in a linear model into a pair of completely testable and completely untestable hypotheses.

**Usage**

```
hypspllit(X, A, xi, tol=sqrt(.Machine$double.eps))
```

**Arguments**

X	Design/model matrix or matrix containing values of explanatory variables (generally including intercept).
A	Coefficient matrix ( $A\beta = \xi$ is the null hypothesis to be split).
$\xi$	A vector ( $A\beta = \xi$ is the null hypothesis to be tested).
tol	A relative tolerance to detect zero singular values while computing generalized inverse, in case X is rank deficient (default = $\sqrt{.Machine\$double.eps}$ ).

**Value**

A list of two objects:

testable	Coefficient matrix and constant vector for testable part of hypotheses.
untestable	Coefficient matrix and constant vector for untestable part of hypotheses.

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
data(denim)
attach(denim)
X <- cbind(1, binaries(Denim), binaries(Laundry))
A <- rbind(c(0,1,0,0,0,0,0), c(0,0,1,0,0,0,0), c(0,0,0,1,0,0,0))
xi <- c(0,0,0)
hypotheses <- hypsplit(X, A, xi, tol=1e-13)
hypotheses[[1]] # testable
hypotheses[[2]] # untestable
detach(denim)
```

---

hypstest

*Test of a linear hypothesis in a linear model*


---

**Description**

Carries out test of a single linear hypothesis in a linear model.

**Usage**

```
hypstest(lmobj, p, xi = 0, type = "both")
```

**Arguments**

<code>lmodj</code>	An object produced by <code>lm</code> fitting.
<code>p</code>	A numeric vector containing coefficients of the linear combination of model parameters.
<code>xi</code>	A numeric variable containing hypothesized value of the linear combination of model parameters (default = 0).
<code>type</code>	A character variable indicating the type of alternative: "upper" (one-sided), "lower" (one-sided) or "both" (default, two-sided).

**Details**

It is assumed that all the model parameters are estimable and the linear model is homoscedastic and normal.

**Value**

Returns the estimated value of the linear combination of model parameters, its standard error, the t-statistic, the degrees of freedom and the p-value.

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
data(lifelength)
lmlife <- lm(Lifelength~factor(Category), data = lifelength)
p <- c(0,0,0,1,-1,0,0,0)
hypptest(lmlife, p, xi = 1, type = "upper")
```

---

imf2015

*IMF unemployment data*


---

**Description**

The estimated or reported figures of a number of economic variables for a few countries in the year 2015, extracted from IMF World Economic Outlook (2017)

**Usage**

```
data(imf2015)
```

**Format**

A data frame with 33 observations on the following 8 variables.

Country Country name, a character vector

CAB Current account balance as % of GDP, a numeric vector

DEBT Governmentt gross debt as % of GDP, a numeric vector

EXP Government total expenditure as % of GDP, a numeric vector

GDP GDP per capita, current prices in '000 US\$, a numeric vector

INFL Inflation, average consumer prices in %, a numeric vector

INV Total investment as % of GDP, a numeric vector

UNMP Unemployment as % of labor force, a numeric vector

**Source**

<http://www.imf.org/external/pubs/ft/weo/2017/01/weodata/weose1gr.aspx>.

**Examples**

```
data(imf2015)
head(imf2015)
```

---

intsectbasis

*Basis of intersection of two column spaces*

---

**Description**

Computes an orthonormal basis of the intersection of column spaces of two given matrices.

**Usage**

```
intsectbasis(A, B, tol1=sqrt(.Machine$double.eps), tol2=sqrt(.Machine$double.eps))
```

**Arguments**

A First matrix.

B Second matrix with identical number of rows.

tol1 A relative tolerance to detect zero singular values while computing generalized inverse, in case the matrix concerned is rank deficient (default =  $\sqrt{\text{.Machine\$double.eps}}$ ).

tol2 A tolerance to detect if there is any non-zero singular value of a 'parallel sum' matrix, without which the intersection space is null (default =  $\sqrt{\text{.Machine\$double.eps}}$ ).

**Value**

Returns a semi-orthogonal matrix with columns forming an orthonormal basis of the intersection of the column spaces of A and B.

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
A<-matrix(2,3,5)
B<-matrix(3,3,2)
intsectbasis(A,B, tol1=sqrt(.Machine$double.eps), tol2=1e-14)
```

---

Iris

*Fisher's Iris data*

---

**Description**

Measurements of four dimensions of flowers of three species of the plant Iris (Iris setosa, Iris versicolor, and Iris virginica).

**Usage**

```
data(Iris)
```

**Format**

A data frame with 150 observations on the following 6 variables.

Species\_No Species number

Petal\_width Petal width (in cm)

Petal\_length Petal length (in cm)

Sepal\_width Sepal width (in cm)

Sepal\_length Sepal length (in cm)

Species\_name Species names: Setosa, Verginica or Versicolor, a character vector

**Source**

Fisher, R.A. (1936) The use of multiple measurements in taxonomic problems. Ann. Eugenics, 7, pp.179-188.

**Examples**

```
data(Iris)
head(Iris)
```

---

`is.included`*Whether one column space is contained in another*

---

**Description**

Checks whether column space of one matrix is a subset of the column space of another matrix.

**Usage**

```
is.included(B, A, tol1=sqrt(.Machine$double.eps), tol2=sqrt(.Machine$double.eps))
```

**Arguments**

B	The matrix whose column space is to be checked for being a subset.
A	The matrix whose column space is to be checked for being a superset.
tol1	A relative tolerance to detect zero singular values while computing generalized inverse, in case A is rank deficient (default = $\sqrt{\text{.Machine\$double.eps}}$ ).
tol2	A relative tolerance to detect whether there is sufficient closeness between B and $A.\text{ginv}(A).B$ (default = $\sqrt{\text{.Machine\$double.eps}}$ ).

**Value**

A logical value (TRUE if the column space of B is contained in the column space of A).

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
A <- cbind(c(2,1,-2),c(3,1,-1))
I <- diag(1,3)
is.included(A, I, tol1=sqrt(.Machine$double.eps), tol2=1e-15)
is.included(I, A, tol1=1e-14, tol2=sqrt(.Machine$double.eps))
is.included(projector(A), A, tol1=1e-15, tol2=1e-14)
is.included(A, projector(A))
```

---

ivif	<i>Intercept augmented variance inflation factors</i>
------	---

---

**Description**

Computes the intercept augmented variance inflation factors for a linear model.

**Usage**

```
ivif(lmobj)
```

**Arguments**

lmobj            An object produced by lm fitting.

**Value**

Returns the intercept augmented variance inflation factors for the model, with each VIF labelled either as (Intercept) or by the variable name.

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
data(imf2015)
lmimf <- lm(UNMP~CAB+DEBT+EXP+GDP+INFL+INV, data = imf2015)
ivif(lmimf)
```

---

kinks	<i>Kink bands in rocks</i>
-------	----------------------------

---

**Description**

Measurements of an angular dimension (beta angle) found in kink bands of Daling phyllite in the Darjeeling-Sikkim Himalayas.

**Usage**

```
data(kinks)
```



**Format**

A data frame with 100 observations on the following 3 variables.

beta Beta angle in kink bands (in degrees)

order Fold order (1 = main fold, 2 = sub-fold, 3,4 = sub-folds of successively higher order)

type Type of kink band (1 = conjugate, 2 = dextral, 3 = sinistral)

**Source**

Sengupta and Jammalamadaka (2019), *Linear Models and Regression with R: An Integrated Approach*, World Scientific Publishing Co., Table 6.8.

**Examples**

```
data(kinks)
head(kinks)
```

---

LAcime

*LA crime and temperature data*

---

**Description**

Monthly total counts of homicides and rapes in the city of Los Angeles from January 1975 to December 1993.

**Usage**

```
data(LAcime)
```

**Format**

A data frame with 228 observations on the following 7 variables.

Year Year of record

Month Month of record

Population Population of the city in the year of record

TempCelsius Monthly average temperature recorded at the Los Angeles International Airport (in Celsius)

Fahrenheit Monthly average temperature recorded at the Los Angeles International Airport (in Fahrenheit)

Homicide Total count of homicides in the month and year of record

Rape Total count of rapes in the month and year of record

**Source**

The crime data: Carlson, S.M. (1998), Uniform Crime Reports: Monthly Weapon-Specific Crime and Arrest Time Series, 1975-1993, ICPSR06792-v1, Interuniversity Consortium for Political and Social Research, Ann Arbor, MI (<https://www.icpsr.umich.edu/icpsrweb/NACJD/studies/6792>). Temperature data for LAX (WMO ID 72295): National Oceanic and Atmospheric Administration, USA (<http://www.ncdc.noaa.gov/ghcnm/v2.php>)

**Examples**

```
data(LAcime)
head(LAcime)
```

---

leprosy

*Treatment of leprosy*


---

**Description**

Pre- and post-treatment scores on abundance of leprosy for patients receiving different treatments (Snedecor and Cochran, 1967).

**Usage**

```
data(leprosy)
```

**Format**

A data frame with 30 observations on the following 3 variables.

treatment Treatment type: A, D or F (placebo), a character vector

pre Pre-treatment score, a numerical vector

post Post-treatment score, a numerical vector

**Source**

Snedecor, G.W. and Cochran, W.G. (1967) Statistical Methods, Iowa State University, Ames, p.421.

**Examples**

```
data(leprosy)
head(leprosy)
```

---

lifelength	<i>Age at death</i>
------------	---------------------

---

**Description**

William Guy's nineteenth century data on the age at death of persons belonging to different professions.

**Usage**

```
data(lifelength)
```

**Format**

A data frame with 690 observations on the following 2 variables.

Category Code for profession: 1 = historian, 2 = poet, 3 = painter, 4 = musician, 5 = mathematician or astronomer, 6 = chemist or natural philosopher, 7 = naturalist, 8 = engineer, architect or surveyor

Lifelength Age (in years) of deceased

**Source**

Guy, W. (1859) On the duration of life as affected by the pursuits of literature, science and art. J. Statist. Soc. London, 22.

**Examples**

```
data(lifelength)
head(lifelength)
```

---

multcomp	<i>Multiple comparison tests</i>
----------	----------------------------------

---

**Description**

Produces p-values of Bonferroni and Scheffe multiple comparison tests of several testable linear hypotheses.

**Usage**

```
multcomp(y, X, A, xi, tol=sqrt(.Machine$double.eps))
```

**Arguments**

y	Response vector in linear model.
X	Design/model matrix or matrix containing values of explanatory variables (generally including intercept).
A	Coefficient matrix (A.beta=xi is the set of multiple hypotheses that has to be tested).
xi	A vector of values (A.beta=xi is the set of multiple hypotheses that has to be tested).
tol	A relative tolerance to detect zero singular values while computing generalized inverse, in case X is rank deficient (default = sqrt(.Machine\$double.eps)).

**Details**

Normal distribution of response (given explanatory variables and/or factors) is assumed.

**Value**

Returns F statistics and p-values of Bonferroni and Scheffe multiple comparison tests of the set of linear hypotheses. A set of five vectors:

A	Specified coefficient matrix.
xi	Specified values of A.beta.
Fstat	Set of F-ratios for each hypothesis.
Bonferroni.p	Set of Bonferroni p-values for different hypotheses.
Scheffe.p	Set of Scheffe p-values for different hypotheses.

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
data(denim)
attach(denim)
X <- cbind(1, binaries(Denim), binaries(Laundry))
A <- rbind(c(0, 1, -1, 0, 0, 0, 0), c(0, 1, 0, -1, 0, 0, 0), c(0, 0, 1, -1, 0, 0, 0))
xi <- c(0, 0, 0)
multcomp(Abrasion, X, A, xi, tol=1e-14)
detach(denim)
```

---

`olympic`*Olympic sprint finals data*

---

**Description**

Times recorded by winners of men's olympic sprint finals in different categories from 1900 to 1988 (Lunn and McNeil, 1991).

**Usage**

```
data(olympic)
```

**Format**

A data frame with 20 observations on the following 6 variables.

Year Olympic year

X100m Winner's time (in seconds) for 100 meters sprint

X200m Winner's time (in seconds) for 200 meters sprint

X400m Winner's time (in seconds) for 400 meters sprint

X800m Winner's time (in seconds) for 800 meters sprint

X1500m Winner's time (in seconds) for 1500 meters sprint

**Details**

There are three missing years in the data; 1916, 1940 and 1944, when world wars prevented the olympic games from being held.

**Source**

Lunn, A.D. and McNeil, D.R. (1991) Computer-Interactive Data Analysis, Wiley, Chichester.

**Examples**

```
data(olympic)
head(olympic)
```

---

poison

*Survival times of poisoned animals*

---

### Description

Survival times of animals exposed to poison and treatment (Box and Cox, 1964).

### Usage

```
data(poison)
```

### Format

A data frame with 48 observations on the following 3 variables.

Survtime Survival time (in 10 hour units)

Treatment Treatment type: 1 = treatment A, 2 = treatment B, 3 = treatment C, 4 = treatment D

Poison Poison type: 1 = Poison I, 2 = Poison II, 3 = Poison III

### Source

Box, G.E.P. and Cox, D.R. (1964) An analysis of transformations. J. Roy. Statist. Soc. Ser. B, 26, pp.211-252.

### Examples

```
data(poison)
head(poison)
```

---

projector

*Orthogonal projector of a matrix*

---

### Description

Computes the orthogonal projection matrix for the column space of a given matrix.

### Usage

```
projector(M, tol=sqrt(.Machine$double.eps))
```

### Arguments

M A matrix for which the orthogonal projection matrix is to be computed.  
 tol A relative tolerance to detect zero singular values while computing generalized inverse, in case M is rank deficient (default =  $\sqrt{\text{.Machine\$double.eps}}$ ).

**Value**

Returns the orthogonal projection matrix for the column space of M.

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
projector(matrix(3,3,3))
```

---

skulls	<i>Egyptian skull development</i>
--------	-----------------------------------

---

**Description**

Measurements of male Egyptian skulls from time periods ranging from 4000 BC to 150 AD.

**Usage**

```
data(skulls)
```

**Format**

A data frame with 150 observations on the following 5 variables.

MB Maximal breadth (in mm)

BH Basibregmatic height (in mm)

BL Basialveolar length (in mm)

NH Nasal height (in mm)

Year Approximate Year of Skull Formation (negative = B.C., positive = A.D.)

**Source**

Thomson, A. and Randall-Maciver, R. (1905) Ancient Races of the Thebaid, Oxford University Press, Oxford.

**Examples**

```
data(skulls)
head(skulls)
```

---

splett2	<i>Energy data</i>
---------	--------------------

---

**Description**

Energy absorbed by four machines for Charpy V-notch testing.

**Usage**

```
data(splett2)
```

**Format**

A data frame with 99 observations on the following 2 variables.

Energy Energy absorbed by machine (in foot-pounds)

Machine Machine type (1 = Tinius1, 2 = Tinius2, 3 = Satec, 4 = Tokyo)

**Source**

Dataplot webpage of the National Institute of Standards and Technology (NIST), USA (<https://www.itl.nist.gov/div898/software/dataplot/data/SPLETT2.DAT>).

**Examples**

```
data(splett2)
head(splett2)
```

---

stars1	<i>Stars data 1</i>
--------	---------------------

---

**Description**

Distance of galactic objects from Earth and their velocities (Hubble, 1929).

**Usage**

```
data(stars1)
```

**Format**

A data frame with 24 observations on the following 2 variables.

Distance Distance from Earth (in million parsec; 1 parsec = 3.26 light years)

Velocity Velocity of galaxy (in km/s)



**Source**

Hubble, E. (1929) A relation between distance and radial velocity among extra galactic nebulae. Proc. Nat. Acad. Sc. 15, pp.168-73.

**Examples**

```
data(stars1)
head(stars1)
```

---

stars2	<i>Stars data 2</i>
--------	---------------------

---

**Description**

Distance of additional galactic objects from Earth and their velocities (Humason, 1936).

**Usage**

```
data(stars2)
```

**Format**

A data frame with 21 observations on the following 2 variables.

Distance Distance from Earth (in million parsec; 1 parsec = 3.26 light years)

Velocity Velocity of Galaxy (in km/s)

**Details**

The galactic objects in this data set are much further away from Earth than those in the data set stars1.txt. These became available within a few years of the publication of Hubble's original work, through rapid advancement in technology. Although the new data cemented Hubble's hypothesis that distant objects have proportionately higher velocity (as they should in a universe expanding with constant acceleration), the constant of proportionality turned out to be somewhat different from Hubble's original estimate.

**Source**

Humason, M.L. (1936) The apparent radial velocities of 100 extra galactic nebula. Astrophys. J. 83, pp.10-22.

**Examples**

```
data(stars2)
head(stars2)
```

---

`supplbasis`*Supplementary basis vectors for column space of a matrix*

---

**Description**

Computes a basis which, together with a basis of some columns of a matrix, constitute a basis of the column space of the entire matrix.

**Usage**

```
supplbasis(A, B, tol=sqrt(.Machine$double.eps))
```

**Arguments**

<code>A</code>	Sub-matrix containing some columns of a matrix.
<code>B</code>	Sub-matrix containing remaining columns of same matrix.
<code>tol</code>	A relative tolerance to detect rank deficiency during qr decomposition (default = $\sqrt{\text{.Machine\$double.eps}}$ ).

**Value**

Returns a semi-orthogonal matrix whose columns, together with a basis of the column space of `A`, constitute a basis of the column space of the entire matrix (`A:B`).

**Author(s)**

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**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
A <- cbind(c(2,1,-2),c(3,1,-1))
B <- diag(c(1,1,0))
supplbasis(A,B)
```

---

tr	<i>Trace of matrix</i>
----	------------------------

---

**Description**

Computes the trace of a given matrix.

**Usage**

```
tr(M)
```

**Arguments**

M                    A matrix whose trace is to be computed.

**Value**

A scalar value, describing the trace of M.

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
tr(matrix(2,2,2))
```

---

trout	<i>Brown trout hemoglobin data</i>
-------	------------------------------------

---

**Description**

The measured hemoglobin content in the blood of brown trout that were randomly allocated to four troughs, where different concentrations of sulfamerazine in food were administered 35 days prior to measurement (Gutsell, 1951).

**Usage**

```
data(trout)
```

**Format**

A data frame with 40 observations on the following 2 variables.

Sulfamerazine Concentrations of sulfamerazine (in grams per 100 pounds of fish)

Hemoglobin Hemoglobin content (in grams per 100 ml of blood)

**Source**

Gutsell, James S. (1951) The effect of sulfamerazine on the erythrocyte and hemoglobin content of trout blood, *Biometrics* 7(2), pp.171-179.

**Examples**

```
data(trout)
head(trout)
```

---

waist

*Waist circumference and adipose tissue data*

---

**Description**

Waist circumference and adipose tissue data (Daniel and Cross, 2013).

**Usage**

```
data(waist)
```

**Format**

A data frame with 109 observations on the following 2 variables.

Waist Waist circumference (in centimeters)

AT Area of lower abdominal adipose tissue (in squared centimeters)

**Source**

Daniel, W.W. and Cross, C.L. (2013) *Biostatistics: A Foundation for Analysis in the Health Sciences*, tenth edition, Wiley, New York, Table 9.3.1.

**Examples**

```
data(waist)
head(waist)
```

---

worldpop	<i>World population data</i>
----------	------------------------------

---

**Description**

The midyear population of the world for the years 1981-2000.

**Usage**

```
data(worldpop)
```

**Format**

A data frame with 20 observations on the following 2 variables.

Year Calendar year

Pop.billion Population (in billion)

**Source**

U.S. Census Bureau, International Data Base (<http://www.census.gov/ipc/www/idbnew.html>)

**Examples**

```
data(worldpop)
head(worldpop)
```

---

worldrecord	<i>World record running times data</i>
-------------	--

---

**Description**

Men's and women's world record times for various out-door running distances, recognized by the International Association of Athletics Federations (IAAF) as of 17 November, 2017.

**Usage**

```
data(worldrecord)
```

**Format**

A data frame with 10 observations on the following 3 variables.

Distance Running distance (in meters)

MenRecord Men's record time (in seconds)

WomenRecord Women's record time (in seconds)

**Source**

International Association of Athletics Federations (<https://www.iaaf.org/records/by-category/world-records>).

**Examples**

```
data(worldrecord)
head(worldrecord)
```

---

Wright

*Wright brothers' wind tunnel data*

---

**Description**

Wright brothers' 1901 wind tunnel data on pressure over different types of wings at different angles.

**Usage**

```
data(Wright)
```

**Format**

A data frame with 222 observations on the following 3 variables.

Pressure Air pressure (in psi)

Angle Angle of wing (in degrees)

Wing Wing type

**Source**

Dataplot webpage of the National Institute of Standards and Technology (NIST), USA (<https://www.itl.nist.gov/div898/software/dataplot/data/WRIGHT11.DAT>)

**Examples**

```
data(Wright)
head(Wright)
```

---

yX	<i>Prepare design matrix for two way layout with single observation per cell</i>
----	--

---

**Description**

Prepares design matrix for two way classified data with single observation per cell and response vector in corresponding order.

**Usage**

```
yX(response, treatments, blocks)
```

**Arguments**

response	Response vector as provided (numeric).
treatments	Vector of treatment levels as provided (either numeric or character).
blocks	Vector of block levels as provided (either numeric or character).

**Value**

Returns a list with following components.

X	A binary matrix with number of rows equal to length of response and number of columns equal to the total number of levels of treatments and blocks plus one. Each row has exactly three 1s: in the first position and in the two positions representing the treatment and block levels.
y	Numeric vector of response values, permuted to correspond with the rows of X.

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
data(airspeed)
yX(airspeed$Posmaxspeed,airspeed$Reynolds,airspeed$Ribht)
```

---

`yXm`*Prepare design matrix for balanced two way layout*

---

**Description**

Prepares design matrix for balanced two way classified data and response vector in corresponding order.

**Usage**

```
yXm(response, treatments, blocks)
```

**Arguments**

<code>response</code>	Response vector as provided (numeric).
<code>treatments</code>	Vector of treatment levels as provided (either numeric or character).
<code>blocks</code>	Vector of block levels as provided (either numeric or character).

**Value**

Returns a list with following components.

<code>X</code>	A binary matrix with number of rows equal to length of response and number of columns equal to the total number of levels of treatments and blocks plus one. Each row has exactly three 1s: in the first position and in the two positions representing the treatment and block levels.
<code>y</code>	Numeric vector of response values, permuted to correspond with the rows of <code>X</code> .

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
data(poison)
yXm(poison$Survtime,poison$Treatment,poison$Poison)
```



---

`yXn`*Prepare design matrix for nested model with groups and subgroups*

---

**Description**

Prepares design matrix for nested model with groups and subgroups and response vector in corresponding order.

**Usage**

```
yXn(response, group, subgroup)
```

**Arguments**

<code>response</code>	Response vector as provided (numeric).
<code>group</code>	Vector of group labels as provided (either numeric or character).
<code>subgroup</code>	Vector of subgroup labels as provided (either numeric or character).

**Value**

Returns a list with following components.

<code>X</code>	A binary matrix with number of rows equal to length of response and number of columns equal to the total number of levels of treatments and blocks plus one. Each row has exactly three 1s: in the first position and in the two positions representing the group and the subgroup.
<code>y</code>	Numeric vector of response values, permuted to correspond with the rows of <code>X</code> .

**Author(s)**

Debasis Sengupta <shairiksengupta@gmail.com>, Jinwen Qiu <qjwsnow\_ctw@hotmail.com>

**References**

Sengupta and Jammalamadaka (2019), Linear Models and Regression with R: An Integrated Approach.

**Examples**

```
data(kinks)
yXn(kinks$beta, kinks$type, kinks$order)
```

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