Package ‘lmPerm’

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Title Permutation Tests for Linear Models
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Imports stats
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Alfalfa Data

Description

Alfalfa data set

Usage

data(Alfalfa)

Author(s)

Bob Wheeler <bwheelerg@gmail.com>

aovp

Fitting and testing ANOVA using permutation tests

Description

aovp is aov modified to use permutation tests instead of normal theory tests. Like aov, the ANOVA model is fitted by a call to lmp for each stratum. Timing differences between aovp and aov are negligible.

Usage

aovp(formula, data = NULL, perm="Exact", seqs=FALSE,
    center=TRUE, projections = FALSE, qr = TRUE,
    contrasts = NULL, ...)

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Arguments

The arguments are the same as for aov. Additional parameters may be included. They are described in the "Additional Parameters" section below. These additional parameters are the same as for lmp.

- **formula**: A formula specifying the model.
- **data**: A data frame in which the variables specified in the formula will be found. If missing, the variables are searched for in the standard way.
- **perm**: "Exact", "Prob", "SPR" will produce permutation probabilities. Anything else, such as "", will produce F-test probabilities.
- **seqs**: If TRUE, will calculate sequential SS. If FALSE, unique SS.
- **center**: If TRUE, numerical variables will be centered.
- **projections**: Logical flag: should the projections be returned?
- **qr**: Logical flag: should the QR decomposition be returned?
- **contrasts**: A list of contrasts to be used for some of the factors in the formula. These are not used for any Error term, and supplying contrasts for factors only in the Error term will give a warning.

... Arguments to be passed to aovp, such as those listed below.

Details

The model \( Y=Xb+Zg+e \) is assumed, where \( X \) is the incidence matrix for fixed effects, and \( Z \) is an incidence matrix for random effects, with columns representing the several error strata. The \( \text{aovp()} \) algorithm projects \( Y \) into strata such that each stratum has a single error term, such as a stratum defined by whole blocks. \( X \) is also projected so that the model in this stratum becomes \( \text{P(Y)}=\text{P(X)b}+\text{e} \).

The vector \( b \) is divided into sources with dfj degrees of freedom for the jth source, and \text{summary(aovp())} will produce an ANOVA table for these sources in the ith strata. See Venables and Ripley for details.

Either permutation test p-values or the usual F-test p-values will be output. Polynomial model terms are collected into sources, so that \( Y^\sim A\times B+I(A^\times 2) \) will contain two sources, one for A with 2 df, and one for B with 1 df. Sources for factors are treated as usual, and polynomial terms and factors may be mixed in one model. The function \text{poly.formula} may be used to create polynomial models, and the function \text{multResp} may be used to create multiresponse matrices for the lhs from variables defined in data.

The Exact method will permute the values exactly. The Prob and SPR methods will approximate the permutation distribution by randomly exchanging pairs of Y elements. The Exact method will be used by default when the number of observations is less than or equal to maxExact, otherwise Prob will be used.

Prob: Iterations terminate when the estimated standard error of the estimated proportion \( p \) is less than \( p\times Ca \). The iteration continues until all sources and coefficients meet this criterion or until \text{maxIter} is reached. See Anscombe (1953) for the origin of the criterion.

SPR: This method uses sequential probability ratio tests to decide between the hypotheses \( p0 \) and \( p1 \) for a strength \((\alpha, \beta)\) test. The test terminates upon the acceptance or rejection of \( p0 \) or if \text{maxIter} is reached. See Wald (1947). The power of the SPR is \( \beta \) at \( p0 \) and increases to \( 1-\beta \) at \( p1 \). Placing \( p0 \) and \( p1 \) close together makes the cut off sharp.
Exact: This method generates all permutations of Y. It will generally be found too time consuming for more than 10 or 11 observations, but note that `aovp` may be used to divide the data into small enough blocks for which exact permutation tests may be possible.

For Prob and SPR, one may set `nCycle` to unity to exchange all elements instead of just pairs at each iteration, but there seems to be no advantage to doing this unless the number of iterations is small – say less than 100.

The SS will be calculated *sequentially*, just as `lm` does; or they may be calculated *uniquely*, which means that the SS for each source is calculated conditionally on all other sources. This is SAS type III, which is also what `drop1()` produces, except that `drop1()` will not drop main effects when interactions are present. The parameter `seqs` may be used to override the default unique calculation behavior.

**Value**

The usual output from `aov`, with permutation p-values instead of normal theory p-values.

- **Iter**: For Prob and SPR: The number of iterations until the criterion is met.
- **Accept**: For SPR: 1 the p0 hypothesis is accepted, and 0 for rejection or when no decision before maxIter occurs.

**Additional Parameters**

These are the same as for `lm`.

- `settings`: If TRUE, settings such as sequential or unique will be printed. Default TRUE
- `useF`: If TRUE, SS/Resid SS will be used, otherwise SS. The default is TRUE
- `maxIter`: For Prob and SPR: The maximum number of iterations. Default 1000.
- `Ca`: For Prob: Stop iterations when estimated standard error of the estimated p is less than Ca*p. Default 0.1
- `p0`: For SPR: Null hypothesis probability. Default 0.05
- `p1`: For SPR: Alternative hypothesis probability. Default 0.06
- `alpha`: For SPR: Size of SPR test. Default 0.01
- `beta`: For SPR: Type II error for SPR test. Default 0.01
- `maxExact`: For Exact: maximum number of observations allowed. If data exceeds this, Prob is used. Default 10.
- `nCycle`: For Prob and SPR: Performs a complete random permutation, instead of pairwise exchanges, every nCycle cycles. Default 1000.

**Note**

There is a vignette with more details and an example. To access it, type `vignette("lmPerm")`

The default contrasts are set internally to (`contr.sum`, `contr.poly`), which means that coefficients are either pairwise contrasts with the last level or polynomial contrasts.
Numerical variables should be centered in order to make them orthogonal to the constant when ANOVA is to be done.

Factors with many levels may cause problems for the methodology used by R. It is designed to work well with both balanced and unbalanced data, but it is best used for factors with no more than four or five levels. If difficulties occur, degrees of freedom for high order sources will be reduced, and sometimes the sources will be omitted entirely. An error message usually accompanies such behavior.

The variables inside the Error() term are treated in the order given. Thus Error(A+B) will usually produce components in the order A,B, with B orthogonalized with respect to A. This may cause confusion for unbalanced block structures.

This function will behave identically to aov() if the following parameters are set: perm="", seq=TRUE, center=FALSE.

Author(s)
Bob Wheeler <bwheelerg@gmail.com>

References
Hald, A. 1952 Statistical theory with engineering applications. Wiley. Table 7.4
Wald, A. (1947) Sequential analysis, Wiley, Sec. 5.3

See Also
summary.aovp, lmp

Examples

## A simple randomized block example.
# There are 7 blocks and 6 treatments. A first
# analysis with blocks as a factor shows block to be significant and treatments not.

data(Hald17.4)
summary(aovp(Y~T+block,Hald17.4))

# Using the block to define a separate error strata tells a different story.
summary(aovp(Y~T>Error(block),Hald17.4))

# There appears to be a linear trend in the blocks. This may be investigated by
# extracting a linear component. The factor L was created by copying the block
# factor and assigning it a linear contrast, like this
# contrasts(L,1)<-contr.poly(7). The analysis then becomes.
summary(aovp(Y~T+L>Error(block),Hald17.4))

# The L factor is not significant under permutation. It is significant when aov()
# is used and the test is the usual F-test.
## Description

Factorial Experiment

## Usage

```r
data(CC164)
```
Details

A three factor experiment involving lettuce plants. Response is the number of lettuce plants emerging after treatment by three levels of either nitrogen or phosphate fertilizer.

Author(s)

Bob Wheeler <bwheelerg@gmail.com>

References


| composite | Test of theroplastic composite |

Description

Data from a factorial experiment.

Usage

data(composite)

Details

A two variable factorial experiment to test the strength of a thermoplastic composite to laser intensity and tape speed.

Author(s)

Bob Wheeler <bwheelerg@gmail.com>

References

Federer 276

Description
Randomized block in three replicates

Usage
data(Federer276)

Details
A seed-gemination test on eight varieties of guayule. Four treatments were applied to lots of seed from the varieties.
A split plot design assigning varieties to whole plots was used. Treatments formed randomized blocks within whole plots. There were three replicates.
The whole plots were nested within replicates

Author(s)
Bob Wheeler <bwheelerg@gmail.com>

References
ghoctane

Author(s)
Bob Wheeler <bwheelerg@gmail.com>

References

ghoctane Octane blends

Description
Gasoline blending mixture experiment

Usage
data(ghoctane)

Details
An octane-blending experiment for a ternary system. Motor-octane ratings were obtained for a seven lattice point design, and two checkpoints.

Author(s)
Bob Wheeler <bwheelerg@gmail.com>

References

Hald17.4 Hald Data

Description
Data from Hald Table 17.4 on p 505.

Usage
data(Hald17.4)

Details
A randomized block experiment with 7 blocks and 6 treatments.
Author(s)
Bob Wheeler <bwheelerg@gmail.com>

References

**lm**

Fitting and testing linear models with permutation tests.

### Description

**lm** is **lm** modified to use permutation tests instead of normal theory tests. Like **lm**, it can be used to carry out regression, single stratum analysis of variance and analysis of covariance. Timing differences between **lm** and **lm** are negligible.

### Usage

```r
lm(formula, data, perm="Exact", seqs=FALSE, center=TRUE, subset, weights, na.action,
    method = "qr", model = TRUE, x = FALSE, y = FALSE, qr = TRUE,
    singular.ok = TRUE, contrasts = NULL, offset, ...)
```

### Arguments

The arguments are mostly the same as for **lm**. Additional parameters may be included. They are described in the "Additional Parameters" section below. These additional parameters are the same as for **aovp**.

- **formula**: a symbolic description of the model to be fit.
- **data**: an optional data frame containing the variables in the model. If not found in data, the variables are taken from `environment(formula)`, typically the environment from which **lm** is called.
- **perm**: "Exact", "Prob", "SPR" will produce permutation probabilities. Anything else, such as ",", will produce F-test probabilities.
- **seqs**: If TRUE, will calculate sequential SS. If FALSE, unique SS.
- **center**: If TRUE will center numerical variables
- **subset**: an optional vector specifying a subset of observations to be used in the fitting process.
- **weights**: an optional vector of weights to be used in the fitting process. If specified, weighted least squares is used with weights weights (that is, minimizing `sum(w*e^2)`); otherwise ordinary least squares is used.
- **na.action**: a function which indicates what should happen when the data contain NAs. The default is set by the na.action setting of options, and is **na.fail** if that is unset. The "factory-fresh" default is **na.omit**. Another possible value is **NULL**, no action. Value **na.exclude** can be useful.
method is the method to be used; for fitting, currently only method = "qr" is supported; method = "model.frame" returns the model frame (the same as with model = TRUE, see below).

model, x, y, qr logicals. If TRUE the corresponding components of the fit (the model frame, the model matrix, the response, the QR decomposition) are returned.

singular.ok logical. If FALSE (the default in S but not in R) a singular fit is an error.

contrasts an optional list. See the contrasts.arg of model.matrix.default.

offset this can be used to specify an a priori known component to be included in the linear predictor during fitting. An offset term can be included in the formula instead or as well, and if both are specified their sum is used.

... additional arguments to be passed.

Details

The usual regression model EY=Xb is assumed. The vector b is divided into sources with dfi degrees of freedom for the ith source, and anova(lmp()) will produce an ANOVA table for these sources. Either permutation test p-values or the usual F-test p-values will be output. Polynomial model terms are collected into sources, so that Y~A+B+I(A^2) will contain two sources, one for A with 2 df, and one for B with 1 df. Sources for factors are treated as usual, and polynomial terms and factors may be mixed in one model. The function poly.formula may be used to create polynomial models, and the function multResp may be used to create a multi-response matrix for the lhs from variables in data.

One may also use summary(lm()) to obtain coefficient estimates and estimates of the permutation test p-values. The Exact method will permute the values exactly. The Prob and SPR methods will approximate the permutation distribution by randomly exchanging pairs of Y elements. The Exact method will be used by default when the number of observations is less than or equal to maxExact, otherwise Prob will be used.

Prob: Iterations terminate when the estimated standard error of the estimated proportion p is less than p*Ca. The iteration continues until all sources and coefficients meet this criterion or until maxIter is reached. See Anscome(1953) for the origin of the criterion.

SPR: This method uses sequential probability ratio tests to decide between the hypotheses p0 and p1 for a strength (alpha, beta) test. The test terminates upon the acceptance or rejection of p0 or if maxIter is reached. See Wald (1947). The power of the SPR is beta at p0 and increases to 1-beta at p1. Placing p0 and p1 close together makes the cut off sharp.

Exact: This method generates all permutations of Y. It will generally be found too time consuming for more than 10 or 11 observations, but note that aovp may be used to divide the data into small enough blocks for which exact permutation tests may be possible.

For Prob and SPR, one may set nCycle to unity to exchange all elements instead of just pairs at each iteration, but there seems to be no advantage to doing this unless the number of iterations is small – say less than 100.

The SS will be calculated sequentially, just as lm() does; or they may be calculated uniquely, which means that the SS for each source is calculated conditionally on all other sources. This is SAS type III, which is also what drop1() produces, except that drop1() will not drop main effects when interactions are present. The parameter seqs may be used to override the default unique calculation behavior.
Value

The usual output from `lm`, with permutation p-values or F-test p-values. The p-values for the coefficients are of necessity, two-sided.

**Iter** For Prob and SPR: The number of iterations until the criterion is met.

**Accept** For SPR: 1 the p0 hypothesis is accepted, and 0 for rejection or when no decision before maxIter occurs.

Additional parameters

These are the same as for `aovp`.

**settings** If TRUE, settings such as sequential or unique will be printed. Default TRUE

**useF** If TRUE, SS/Resid SS will be used, otherwise SS. The default is TRUE

**maxIter** For Prob and SPR: The maximum number of iterations. Default 1000.

**Ca** For Prob: Stop iterations when estimated standard error of the estimated p is less than Ca*p. Default 0.1

**p0** For SPR: Null hypothesis probability. Default 0.05

**p1** For SPR: Alternative hypothesis probability. Default 0.06

**alpha** For SPR: Size of SPR test. Default 0.01

**beta** For SPR: Type II error for SPR test. Default 0.01

**maxExact** For Exact: maximum number of observations allowed. If data exceeds this, Prob is used. Default 10.

**nCycle** For Prob and SPR: Performs a complete random permutation, instead of pairwise exchanges, every nCycle cycles. Default 1000.

Note

There is a vignette with more details and an example. To access it, type vignette("lmPerm")

The default contrasts are set internally to `(contr.sum, contr.poly)`, which means that factor coefficients are either pairwise contrasts with the last level or polynomial contrasts.

Numerical variables should be centered in order to make them orthogonal to the constant when ANOVA is to be done.

This function will behave identically to `lm()` if the following parameters are set: perm="", seq=TRUE, center=FALSE. An exception for multiple responses is that an ANOVA table for each response is output instead of a call to `anova.mlm()`.

Author(s)

Bob Wheeler <rwheeler@echip.com>
References


Wald, A. (1947) Sequential analysis, Wiley, Sec. 5.3


See Also

summary.lmp, aovp

Examples

# 3x3 factorial with ordered factors, each is average of 12.
# This is a saturated design with no df for error. The results tend to support
# Cochran and Cox who used a guessed residual SS for their analysis. The design
# is balanced, so the sequential SS are the same as the unique SS.
data(CC164)
summary(lmp(y ~ N * P, data = CC164, perm="")) # F-value output as if lm() was used.
summary(lmp(y ~ N * P, data = CC164,)) # Default, using "Exact" if possible.
summary(lmp(y ~ N * P, data = CC164, perm="SP"))
aov(lmp(y ~ N * P, data = CC164))

# A two level factorial. The artificial data is N(0,1) with an effect of
# 1.5 added to factor X4. When the number of iterations are small, as in
# this case, using nCycle=1 is advantageous.
X<-expand.grid(X1=1:2,X2=1:2,X3=1:2,X4=1:2)
X$Y<-c(0.99,1.34,0.88,1.94,0.94,0.63,0.29,-0.78,-0.89,0.43,-0.03,0.50,1.66,1.65,1.78,1.31,1.51)
summary(lmp(Y~(X1+X2+X3+X4)^2,X,"SP")) # The prob method is used because "SP" is not recognized.
summary(lmp(Y~(X1+X2+X3+X4)^2,X,"SPR"))
summary(lmp(Y~(X1+X2+X3+X4)^2,X,"SPR",nCycle=1)) #An additional parameter being passed.

# A saturated design with 15 variables in 16 runs. The original analysis by Quinlan pooled the mean
# squares from the 7 smallest effects and found many variables to be significant. Box, reanalyzed
# the data using half-normal plots and found only variables E and G to be important. The permutation
# analysis agrees with this conclusion.
data(Quinlan)
summary(lmp(SN~.,Quinlan))

# A design containing both a polynomial variable and a factor
data(simDesignPartNumeric)
aov(lmp(poly.formula(Y~quad(A,B)+C),simDesignPartNumeric))
manly126  

Description

Lizard data

Usage

data(manly126)

Details

Two factor data showing ant consumption by lizards. In addition, three additional columns, v1, v2, v3, are included representing the additions used by Manly to calculate power.

Author(s)

Bob Wheeler <bwheelerg@gmail.com>

References


manly136  Non normal Ephemeroptera counts

Description

Ephemeroptera counts from New Zealand streams.

Usage

data(manly136)

Author(s)

Bob Wheeler <bwheelerg@gmail.com>

References

**Description**

This function creates a multiple response matrix for its argument variables. When used on the lhs of the formula in lmPerm() or aovp() it will create a matrix containing one or more response columns from variables defined in the data argument.

**Usage**

```
multResp(...)```

**Arguments**

```
...  Variable names separated by commas.
```

**Value**

A matrix with named columns

**Author(s)**

Bob Wheeler <bwheelerg@gmail.com>

Please cite this program as follows:


**Examples**

```
A<-1:5
B<-1:5
multResp(A,B)

data(Plasma)
anova(lmp(multResp(Amin,Pct,sinpoly)-.,Plasma))```
**NPK**

**NPK Data**

**Description**

Data from Venables and Ripley, Table 6.1, p176.

**Usage**

```r
data(NPK)
```

**Details**

A fractional factorial with blocks confounded with the three way interaction.

**Author(s)**

Bob Wheeler <bwheelerg@gmail.com>

**References**


---

**permute**

**Permutation Generation**

**Description**

Generates permutations a pair at a time.

**Usage**

```r
permute(N=4,K=1,initialize=0)
```

**Arguments**

- **N**
  - The number of elements in the permutation vector. The elements are numbered 1:N
- **K**
  - The number of exchange pairs to be returned at each access
- **initialize**
  - Set to 1 to initialize. Set to 0 for additional pairs.
Details

On first call, set initialize to 1. On subsequent accesses, initialize should be 0. The function returns at most K exchange pairs at each access. The function should be repeatedly called until result is false.

The function returns a list.

Value

<table>
<thead>
<tr>
<th>result</th>
<th>Returns false when the last permutation has been generated or a failure has occurred. Returns true for success and at most K new pairs in vec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>The input parameter</td>
</tr>
<tr>
<td>K</td>
<td>The input parameter</td>
</tr>
<tr>
<td>vec</td>
<td>A 2*K vector of element numbers to be exchanged – permutations may be obtained by successively applying these pairs.</td>
</tr>
<tr>
<td>initialize</td>
<td>Always returns 1</td>
</tr>
<tr>
<td>count</td>
<td>The number of pairs in vec. It may be less than K for the final set.</td>
</tr>
</tbody>
</table>

Note

This is the minimum time and effort routine. It is used for Exact permutation calculations. The present function is a wrapper for the C code and may be useful for other purposes. The code follows Reingole and Nievergelt (1977).

Author(s)

Bob Wheeler <rwheeler@echip.com>

References


Plasma

Plasma Etching

Description

An experiment designed to guide optimization of a nitride etch process

Usage

data(Plasma)
Details

An orthogonal array, capable of supporting a linear model only. The factors are denoted by their units of measurement. They were W, the power applied to the cathode; mTorr, the pressure in the reaction chamber; cm, gap between anode and cathode; sscm, flow of the reactant gas. The three responses: Amin, etch rate; Pct, uniformity; sinpoly, selectivity.

Author(s)

Bob Wheeler <bwheelerg@gmail.com>

References


Description

Formulas are expanded to accommodate special functions for continuous and mixture variables.

Usage

poly.formula(frml)

Arguments

frml A formula using ~ in the usual way.

Details

This function expands formulas to accommodate polynomial models for which R has minimal support. Assuming for illustration that there are three variables, A, B, and C, the following expressions may be used.

All arguments to quad(), cubic(), and cubicS() must be numeric.

- quad(A,B,C) makes \((A + B + C)^2 + I(A^2) + I(B^2) + I(C^2)\)
- cubic(A,B,C) makes \((A + B + C)^3 + I(A^2) + I(B^2) + I(C^2) + I(A^3) + I(B^3) + I(C^3)\)
- cubicS(A,B,C) makes \((A+B+C)^3+I(A*B*(A-B))+I(A*C*(A-C))+I(B*C*(B-C))\)

The cubicS() function produces a non-singular representation of a cubic model, when the variables are mixture variables, that is when the rows of data sum to a constant value, usually 1.0. Because of the mixture constraint, models containing mixture variables should not have a constant term. The linear and quadratic models for mixture variables A, B, and C are given by \(-1 + (A + B + C)\) and \(-1 + (A + B + C)^2\) respectively. See Gorman and Hinman [1962] for details.
Value

An expanded formula is returned.

Author(s)

Bob Wheeler <bwheelerg@gmail.com>

Please cite this program as follows:


References


Examples

poly.formula(y~quad(A,B,C)+Error(block))

Quinlan Quinlan's data

Description

Data from a Symposium on Taguchi Methods, analyzed by G.E.P. Box

Usage

data(Quinlan)

Details


Author(s)

Bob Wheeler <bwheelerg@gmail.com>

References


ratGenotype

**Description**

Data from Scheffe, p140

**Usage**

```r
data(ratGenotype)
```

**Details**

An unbalanced design. The data originally appeared in Bailey (1953), and was reproduced in Scheffe (1959) with the description:

"...gives the weight of hybrid female rats in a foster-nursing experiment with four types of rats. (The weights are litter averages in grams at 28 days. The within litter variance was obviously negligible compared to the between-litter variance.) The factors in the two-way laout are the genotype of the foster mother and that of the litter."

**Author(s)**

Bob Wheeler <bwheelerg@gmail.com>

**References**


---

simDesign

**Description**

A three factor design created using AlgDesign, with a normal response.

**Usage**

```r
data(simDesign)
```

**Author(s)**

Bob Wheeler <bwheelerg@gmail.com>
**A non-orthogonal design**

**Description**
A three factor design created using AlgDesign, with a normal response.

**Usage**
```r
data(simDesignPartNumeric)
```

**Author(s)**
Bob Wheeler <bwheelerg@gmail.com>

**summary**

**Summarizing functions for linear models**

**Description**
Replaces corresponding functions in base package.

**Usage**
```r
## S3 method for class 'lm'
summary(object, correlation = FALSE, symbolic.cor = FALSE, ...)
## S3 method for class 'mlmp'
summary(object, ...)
## S3 method for class 'summary.lmp'
print(x, digits = max(3,getOption("digits") - 3),
symbolic.cor = x$symbolic.cor,
signif.stars = getOption("show.signif.stars"), ...)
## S3 method for class 'aovp'
summary(object, intercept = FALSE, split,
expand.split = TRUE, keep.zero.df = TRUE, ...)
## S3 method for class 'lm'
anova(object, ...)
```

**Arguments**

Same as for the corresponding functions in base package:
- **object** an object of class "lm", usually, a result of a call to `lm`.
- **correlation** logical; if TRUE, the correlation matrix of the estimated parameters is returned and printed.
digits: the number of significant digits to use when printing.
symbolic.cor: logical. If TRUE, print the correlations in a symbolic form (see symnum) rather than as numbers.
signif.stars: logical. If TRUE, “significance stars” are printed for each coefficient.
intercept: logical: should intercept terms be included?
split: an optional named list, with names corresponding to terms in the model. Each component is itself a list with integer components giving contrasts whose contributions are to be summed.
expand.split: logical: should the split apply also to interactions involving the factor?
keep.zero.df: logical: should terms with no degrees of freedom be included?
...
further arguments passed to or from other methods.

Details

These modified functions are needed because the perm values, which are attached to the object, replace the usual test columns in the output from these functions.

Author(s)

Bob Wheeler <rwheeler@echip.com>
Author(s)

Bob Wheeler <rwheeler@echip.com>

Examples

data(Alfalfa)
summaryC(aovp(Yield~Variety*Date+Error(Block/Variety),Alfalfa))

Description

A three factor experiment with non-normal response

Usage

data(wool)

Details

There are three, 3-level factors:

- **len**: length of test specimen in mm
- **amp**: amplitude of loading cycle in mm
- **load**: the load in g

The response was the number of cycles to failure of worsted yarn under cycles of repeated loading

Author(s)

Bob Wheeler <bwheelerg@gmail.com>

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